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All About Space

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WELCOME TO THE COLDEST PLACE IN THE COSMOS

EXCLUSIVE INTERVIEW
ISS ASTRONAUT VICTOR GLOVER

SPECIAL REPORT
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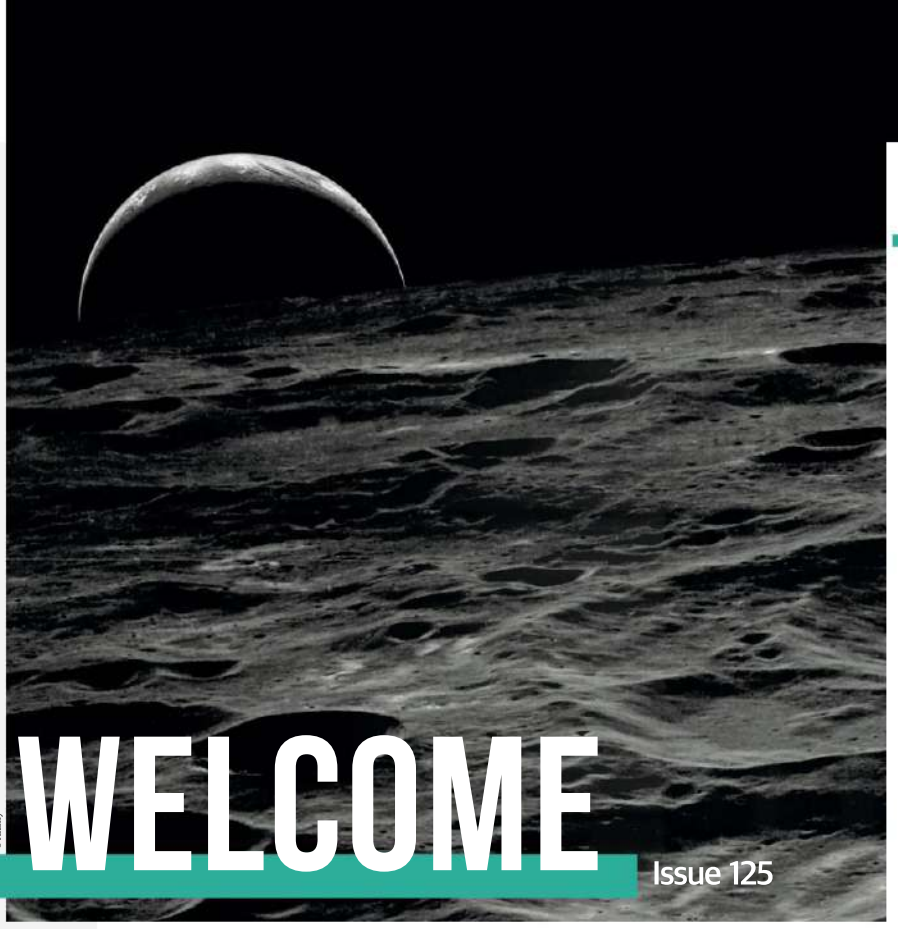

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WELCOME

Issue 125

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NASA astronaut Victor Glover

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With the New Year upon us, many will be making their New Year's resolutions. Some will be promising themselves to get started in astrophotography – if that's you, don't forget to check out last issue for tips and tricks – while others will be looking to spend more time improving their knowledge about the universe, whether that's through a course or just by reading all about it.

Space agencies like NASA and the European Space Agency made plans for 2022 years ago, scheduling mission launches, planetary flybys and, of course, coming up with brand-new roadmaps for the next set of spacecraft to conquer the cosmos. Turn to page 28 to discover what's in store.

If you've spent a lot of time outdoors in the Northern Hemisphere lately, you've no doubt had to wrap up warm. It's the coldest time of the year, but luckily not as cold as the Boomerang Nebula, which according to measurements is much chillier than Antarctica. At a teeth-chattering -272.15 degrees Celsius (-457.87 degrees Fahrenheit), this young planetary nebula with a star dying at its centre is the coldest place in the universe. In our cover feature, you can discover everything you need to know about it – just skip to page 14.

I wish you all a very happy New Year – thanks for being part of the **All About Space** community!

GEMMA LAVENDER

CONTENT DIRECTOR

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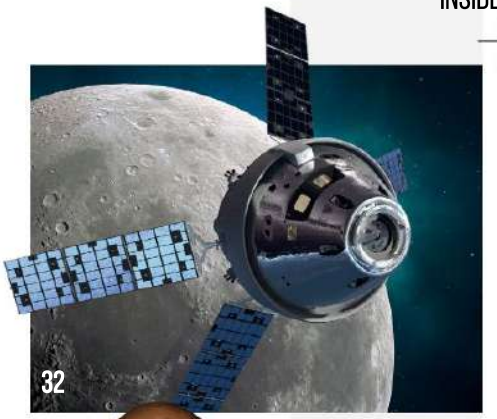

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18 NOVEMBER 2021

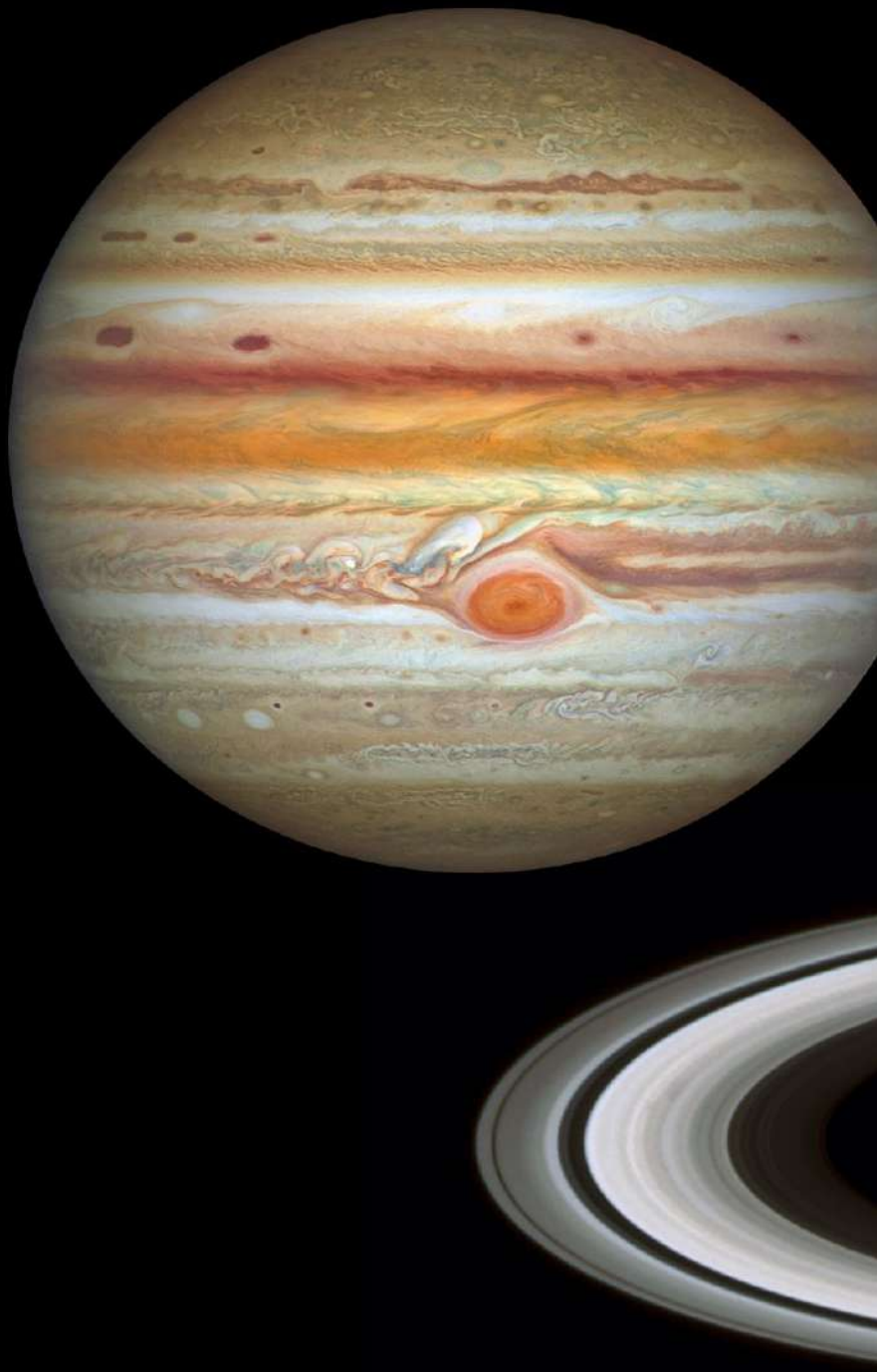
Hubble's planets

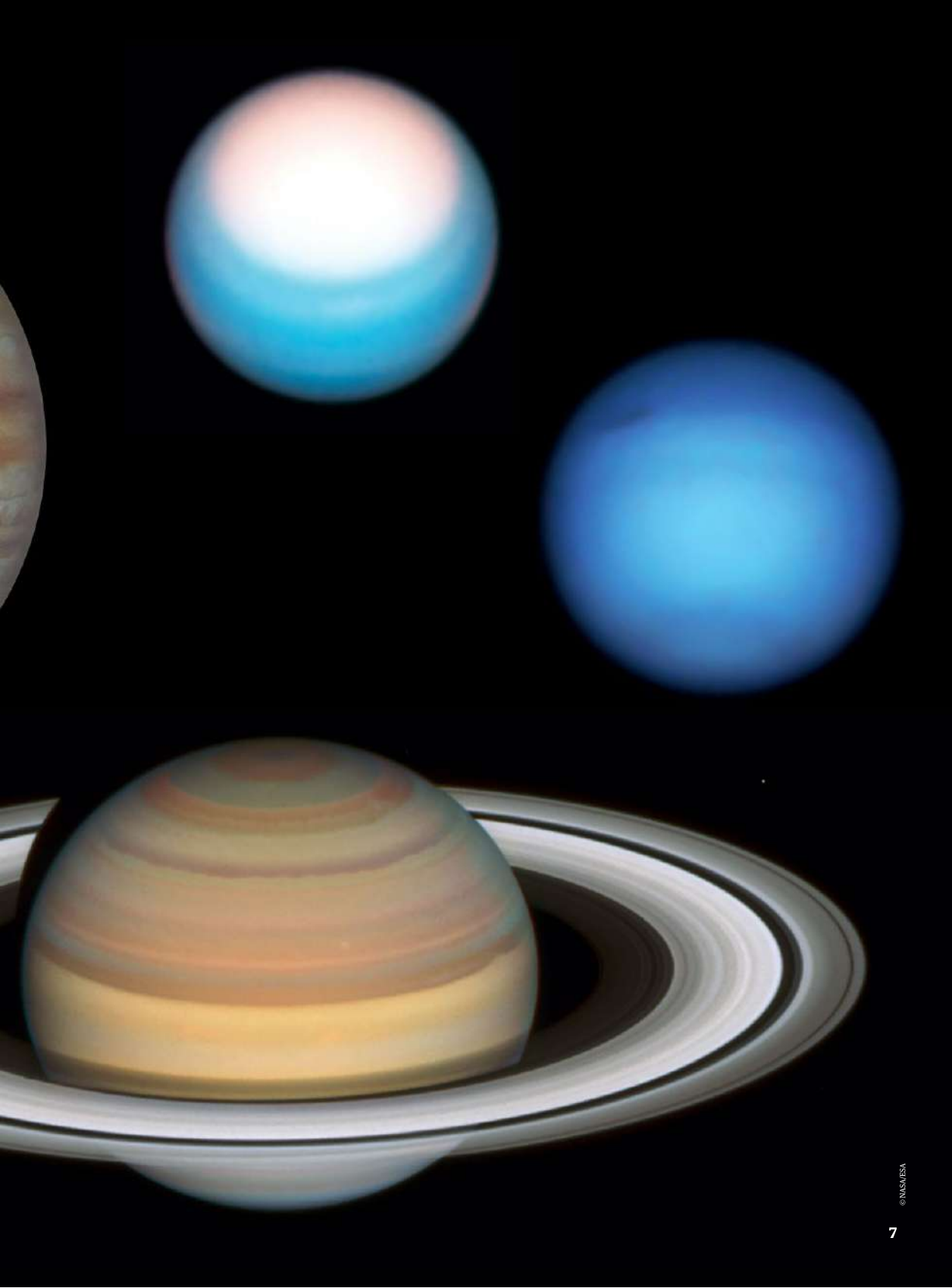
This year's view of Jupiter's ever-changing atmosphere shows several new storms and colour differences near the equator. Taken on 4 September 2021, the image captured a darker, more reddish equator than expected and several bright-red elongated storms.

Hubble's latest view of Saturn, taken on 12 September 2021, captures the planet's northern hemisphere entering early autumn. This seasonal change triggers rapid and extreme colour changes of the yellow and gold bands in the atmosphere, which are caused by superfast winds.

It's spring in the northern hemisphere on Uranus, meaning the north pole is pointed towards the Sun. Because of the dramatic tilt of the planet's axis – nearly 90 degrees – that's a stark change. Spring's increase in ultraviolet radiation absorbed from the Sun alters the concentration of methane gas and haze particles in the planet's atmosphere, causing the polar region to brighten.

Neptune's northern hemisphere is darker than usual and shows a giant storm, represented by a dark spot, in an image captured by Hubble on 7 September 2021. This dark storm – which scientists estimate is wider than the Atlantic Ocean – has moved around the planet since it was first spotted by Hubble in 2018. In the new image, the storm has reversed direction and is moving back north.





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23 NOVEMBER 2021

A curious landscape

New images snapped by NASA's Curiosity rover showcase the stunning, expansive landscape of Mars. The robotic explorer, which launched to the Red Planet on 26 November 2011, continues to roam the Martian terrain. Recently, the Curiosity rover travelled to the side of Mars' Mount Sharp, or Aeolis Mons, a mountain that forms the central peak of Gale crater. There, mission team members captured the beauty of the natural Martian landscape with Curiosity's navigation cameras. Since Curiosity landed in August 2012, it has been exploring the Martian surface, gathering valuable scientific data and images. The rover is in great shape a decade after launch.

© NASA/JPL-Caltech

19 NOVEMBER 2021

A feast for your eyes

Hubble captured this stunning view of the Prawn Nebula. Officially designated IC 4628, it's an emission nebula located 6,000 light years from Earth in the constellation of Scorpius. Nebulae, clouds of interstellar gas and dust, form following massive stellar explosions; in turn, this interstellar material gives life to new stars. Stretching over 250 light years wide, IC 4628 is believed to be a massive stellar nursery, where new stars are forming. Scientists classify it as an emission nebula because its gas has been energised, or ionised, by the radiation of nearby stars. That process produces electrons that re-emit the absorbed energy in the form of infrared light.

© NASA/ESA

ELUSIVE NEUTRINO CANDIDATES DETECTED IN BREAKTHROUGH PHYSICS EXPERIMENT

Words by Chelsea Gohd

For the first time ever, researchers have detected neutrino candidates produced by the Large Hadron Collider (LHC) at the CERN facility near Geneva, Switzerland. In a major milestone in particle physics, researchers report observing six neutrino interactions during an experiment at the LHC. Neutrinos are subatomic particles that have a very small mass, like an electron, but have no electrical charge – a characteristic that has made them extremely challenging to detect.

These neutrinos were created during the inaugural run of an emulsion detector that was combined with CERN's Forward Search Experiment (FASER) collaboration in 2018. "Prior to this project, no sign of neutrinos has ever been seen at a particle collider," said Jonathan Feng, a physics and astronomy professor at the University of California, Irvine, and coleader of the FASER collaboration.. "This significant breakthrough is a step towards developing a deeper understanding of these elusive particles and the role they play in the universe."

The LHC generally works by colliding two high-energy particle beams with one another close to the speed of light. When the charged particles, like protons, smash into one another at such high speeds, the energy of the impact becomes matter in the form of new particles or subatomic particles, so the LHC can essentially 'produce' subatomic particles. In this run at the LHC, the team was running a pilot test with a new emulsion detector instrument that's made up of dense metal plates of lead and tungsten interspersed with layers of emulsion.

Emulsion plates or layers work a lot like old-school photography film. When film strips are exposed to light, photons show themselves as images as the film develops. Similarly with this instrument, when exposed to the particle collisions the emulsion layers revealed neutrino interactions after being processed. Particles colliding during this test produced neutrinos that then smashed into nuclei in the dense metal of the plates. The resulting particles travelled through emulsion layers and created observable 'imprints' left behind.

"THIS IS THE BEGINNING OF A HIGHLY AMBITIOUS QUEST TO DETECT INTERACTIONS"

This reported detection of neutrino interactions reveals two major things. "First, it verified that the position forward of the ATLAS [A Toroidal LHC Apparatus] interaction point at the LHC is the right location for detecting collider neutrinos," Feng said. "Second, our efforts demonstrated the effectiveness of using an emulsion detector to observe these kinds of neutrino interactions."

This is just the beginning of a highly ambitious quest to detect neutrino interactions and continue to explore the strange world of subatomic particles, confirmed David Casper, a FASER project coleader and associate professor at UCI. "Given the power of our new detector and its prime location at CERN, we expect to be able to record more than 10,000 neutrino interactions in the next run of the LHC, beginning in 2022," said Casper. "We will detect the highest energy neutrinos that have ever been produced from a human-made source."

The FASER team has big plans for exploring dark matter at the LHC as well. The team is working towards an experiment with FASER instruments to try and detect so-called 'dark photons', which scientists expect to reveal the behaviour and nature of dark matter.

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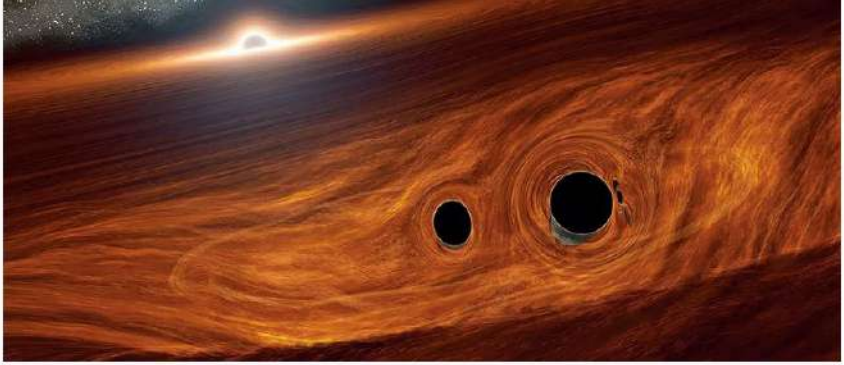

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DID ASTRONOMERS SEE THE LIGHT FROM TWO BLACK HOLES COLLIDING FOR THE FIRST TIME?

Words by Chelsea Gohd

So far the only way astronomers have been able to 'observe' black holes colliding is by detecting the resulting gravitational waves. Since the first detection in 2015, scientists have observed gravitational waves, working to understand their origins. Because black holes have a gravitational pull so strong that not even light can escape, they're difficult to observe, and astronomers have yet to visually identify a collision between two black holes... that is, until now.

While black holes are dark, there are theories that suggest collisions or mergers between black holes could produce a light signal through the material that surrounds them by causing matter to radiate. A team of astronomers using the Zwicky Transient Facility (ZTF) at the Palomar Observatory in California think they may have detected such a light signal. The gravitational wave created by the merger was detected on 21 May 2019 by two different gravitational-wave detectors: Virgo and the Laser Interferometer Gravitational-wave Observatory (LIGO). The wave they detected stems from a collision event dubbed GW190521g that the team thinks could possibly be from two black holes. With this detection, a team of astronomers used the ZTF to peer out into the cosmos and search for light signals from the collision. If confirmed, this would be the first time visible light would be used as evidence of two black holes colliding and creating a gravitational wave.

Above: Black holes are dark, but a new observation could shed some light

TRAPPIST-1 ALIEN SYSTEM WAS NOT BOMBARDED BY SPACE ROCKS LIKE EARLY EARTH

Words by Tereza Pultarova

TRAPPIST-1 would be an unremarkable star if not for the scientific interest generated by its seven planets. Located some 40 light years away from the Sun in the constellation of Aquarius, TRAPPIST-1 is a cool, dim star called a red dwarf, the type that is most common in our galaxy, the Milky Way. Around the star, seven exoplanets about the size of Earth – referred to by simple letters from TRAPPIST-1 b to h based on their distance from the star – orbit in a way that astronomers call 'resonant.' Resonance means that although each planet takes a different amount of time to complete one orbit, pairs regularly meet again at the same starting point.

For example, for every eight orbits completed by planet TRAPPIST-1 b, which is closest to the star, planet c makes five laps, planet d four and planet e two orbits. Scientists argue that this strangely regular orbital dance wouldn't be possible if those planets were subjected to too much hammering by space rocks after their birth in the protoplanetary disc that surrounded the newly formed TRAPPIST-1 star some 7 billion years ago.

"We figured out that after these planets formed, they weren't bombarded by more than a very small amount of stuff," said astrophysicist Sean Raymond of the University of Bordeaux in France. "That's kind of cool. It's interesting information when we're thinking about other aspects of the planets in the system." The model suggests that planets in the TRAPPIST-1 system must have formed very early and very fast, in about one-tenth of the time that it took our Earth to form.

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Below: The planets of TRAPPIST-1 orbit in a pattern

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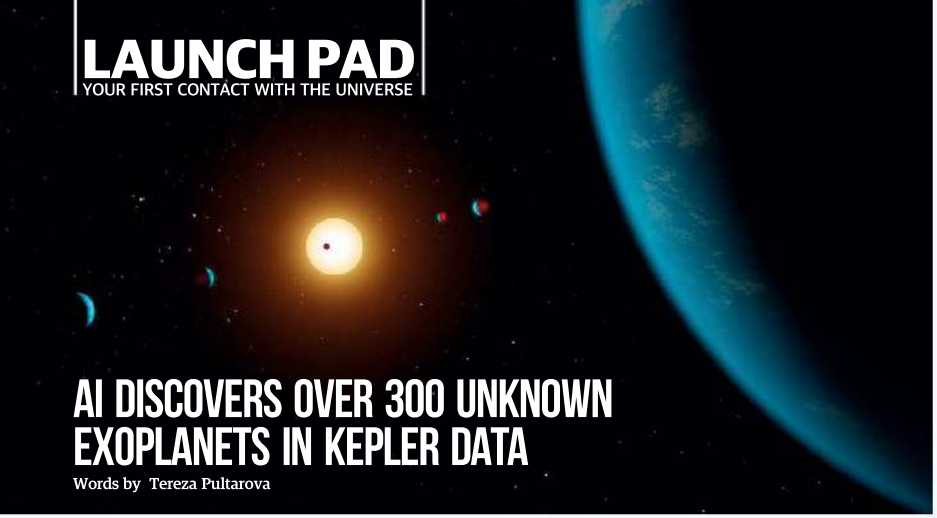

AI DISCOVERS OVER 300 UNKNOWN EXOPLANETS IN KEPLER DATA

Words by Tereza Pultarova

© NASA/JPL-Caltech

Kepler, NASA's first dedicated exoplanet hunter, has observed hundreds of thousands of stars in the search for worlds outside our Solar System. The catalogue of potential planets it compiled continues generating new discoveries even after the telescope's demise. Human experts analyse the data for signs of exoplanets. But a new algorithm called ExoMiner can now mimic that procedure and scour the catalogue faster and more efficiently.

The telescope, which stopped working in 2018, looked for temporary decreases in the brightness of stars that might be caused by a planet crossing in front of the star's disc as seen from Kepler's perspective. But not all such dimming events are caused by exoplanets, and scientists had to follow elaborate procedures to distinguish false positives.

ExoMiner is a so-called neural network, a type of artificial intelligence algorithm that can learn and improve its abilities when fed a sufficient amount of data. And Kepler generated plenty of data: in its less than ten years of service, the telescope discovered thousands of planet candidates, nearly 3,000 of which have since been confirmed – that's a vast majority of the overall 4,569 exoplanets currently known.

Now ExoMiner has proven its skills, scientists are looking to use it to help sift through data from other existing and upcoming exoplanet-searching missions, such as NASA's current Transiting Exoplanet Survey Satellite (TESS) or the European Space Agency's Planetary Transits and Oscillations of Stars (PLATO) mission that will launch in 2026.

Above: An algorithm is helping to sort masses of data

ROCKET LAB AIMS TO CATCH A FALLING ELECTRON BOOSTER WITH A HELICOPTER

Words by Mike Wall

Rocket Lab plans to pluck the falling first stage of one of its Electron launchers out of the sky with a helicopter on its next recovery mission. The timeline is not yet set, but this dramatic aerospace feat is likely to happen soon. "We certainly hope to have that flight within the first half of next year," Rocket Lab founder and CEO Peter Beck said. "Or as soon as practically possible, really."

California-based Rocket Lab is working to make the first stage of the Electron reusable, an advance that would boost launch rates and reduce costs. The ultimate recovery strategy involves bringing boosters down slowly under a parachute and catching them in mid-air with a helicopter, which will haul them back to land for inspection, refurbishment and reflight.

The company has already made considerable progress towards this goal. It's recovered Electron first stages during orbital launches three times to date, most recently on 17 November. Those were maritime operations; the boosters splashed down in the Pacific Ocean, offshore from Rocket Lab's New Zealand launch site, and were hauled aboard a boat for the trip. A helicopter was involved in the most recent recovery, a mission that Rocket Lab called 'Love At First Insight'. The chopper didn't try to snag the booster, but it was stationed in the recovery zone to test booster tracking and communications among the helicopter team, mission control and the recovery ship.

© Rocket Lab

Left: Reusable stages make spaceflight cheaper and more accessible

Right: Solar sails harvest solar energy in a different way to solar panels

IN COOPERATION WITH SPACE.com

LIGHTSAIL 2 SOLAR SAIL IS STILL SOARING ABOVE EARTH MORE THAN TWO YEARS AFTER LAUNCH

Words by Tereza Pultarova

An experimental spacecraft testing solar sails as a means of cost-effective space propulsion that could power future missions to distant places is still riding the sunbeams in Earth's orbit more than two-and-a-half years after its launch. The spacecraft is a cubesat about the size of a loaf of bread, fitted with a solar sail the size of a boxing ring, or about 32 square metres (433 square feet). This sail captures incoming photons from the Sun, just as a wind sail catches the moving air, to propel the spacecraft.

LightSail 2 is a private project of the Planetary Society, a US-headquartered space education and outreach nonprofit organisation. But the results of the experiment have already informed the design of upcoming NASA missions such as Near-Earth Asteroid Scout, Solar Cruiser and the Advanced Composite Solar Sail System. NEA Scout, one of the 'passengers' on NASA's upcoming Moon-bound Artemis 1 mission, will use the solar propulsion technology to leave the Moon's orbit and visit a near-Earth asteroid.

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PHILIP'S STARGAZING WITH BINOCULARS

Providing a comprehensive guide to the very best night-sky objects for binocular observation, this book by astronomers Robin Scagell and David Frydman is ideal for those just breaking into touring the heavens. *Philip's Stargazing with Binoculars* gives practical help for setting up and using binoculars of any size and pinpointing the best targets to turn your gaze to, whether you're in a light-polluted town or under dark skies.

To be in with a chance of winning, answer this question:

What are the ejections of material that erupt from the surface of the Sun called?

A: Solar flares **B:** Sunspots **C:** Photospheres

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FROZEN UNIVERSE

IT'S TIME TO WRAP UP WARM AND EXPLORE THE BOOMERANG NEBULA – A PECULIAR PLACE WITH THE COLDEST KNOWN NATURAL TEMPERATURE

Reported by David Crookes

In the Northern Hemisphere, we're currently feeling temperatures drop. But while it certainly feels pretty cold, we'd hazard a guess that the temperature hasn't dropped as low as the -93.2 degrees Celsius (-199.8 degrees Fahrenheit) recorded across Dome Fuji, Antarctica, in 2010. A visit there would require the thickest of coats and a vacuum flask topped up with a steaming-hot beverage. Yet imagine venturing somewhere even colder than that - a journey to the coldest place in the universe, in fact. You'll need to crack the secret of a very long life and some clever scientist will have to work out how to travel at the speed of light, but a cold welcome awaits nonetheless.

Should you be up for the challenge, your destination will be the Boomerang Nebula, a reflecting cloud of dust and ionised gases

© Tobias Roetsch

© NASA

BOOMERANG NEBULA BY NUMBERS

5,000
light years away from Earth

x10
It ejects matter ten times faster than a single star could on its own

3 TRILLION
The outflow stretches more than 3 trillion kilometres end to end

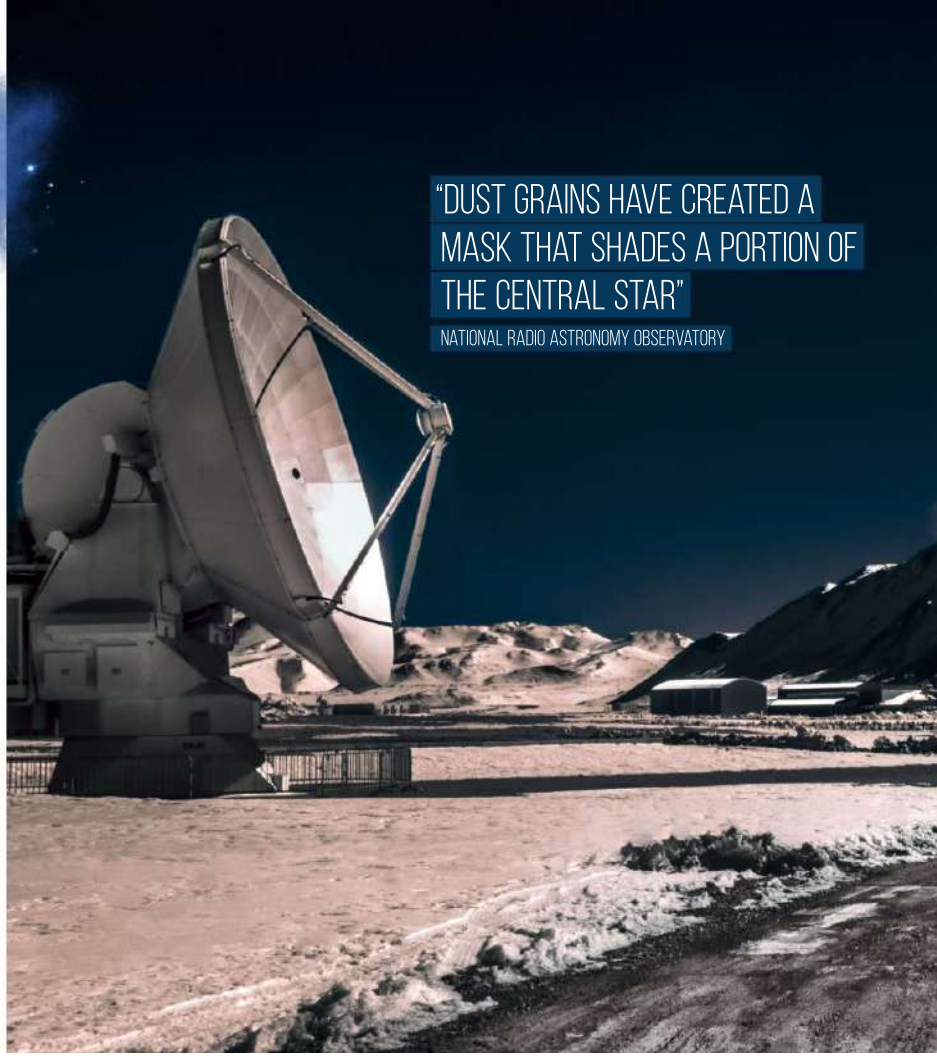
ONE
Each lobe is one light year in length

100,000
The Milky Way is about 100,000 light years across

21,000
times the distance between the Sun and Earth

150KM
The outflow is travelling at 150 kilometres per second

1980
The year the name was coined



© ESO

Above: One of the 12-metre (39.4-foot) antennae that make up ALMA

Right: ALMA data of the Boomerang Nebula with a red filter applied

and the coldest known place in the universe. This preplanetary nebula with a dying star at its centre is located some 5,000 light years from Earth in Centaurus, and it's so utterly freezing that if you ever did make it there, you'd be unlikely to ever come back, regardless of its name. To give you an idea of how cold it is, let's recap the lowest limit of the thermodynamic temperature scale: absolute zero. On the Celsius scale this is -273.15 degrees, and on the Fahrenheit scale it's -459.67 degrees. Since the Boomerang Nebula's deep interior temperature is a teeth-chattering -272 degrees Celsius or -458 degrees Fahrenheit, this places it just a degree Celsius above absolute zero. That makes it a whopping three times chillier than the temperature recorded across Dome Fuji.

When the Boomerang Nebula was discovered in 1979, no one had any idea that it would become so significant. Astronomers had been surveying the southern sky, labelling this 'peculiar object' as ESO 172-07. The same year, it was identified as a nebula by Gary Wegner and Ian Glass from the South African Astronomical Observatory, prompting astronomers Keith Taylor and Mike Scarrott to study it in 1980 using the Anglo-Australian ground-based telescope at Siding Spring Observatory. What they saw intrigued them.

ESO 172-07, they noted, had a distinctive boomerang shape, which they understood was caused by gas being ejected in opposite directions from a central object. Yet despite giving it the name the Boomerang Nebula, the object sat in the background of academia until ten years later, when in 1990 astronomer Raghvendra Sahai predicted the existence of cold regions in a paper published in the Astrophysical Journal.

Sahai noted that strong winds from extreme objects could flow outwards at high speeds while

GETTING A GLIMPSE OF THE BOOMERANG NEBULA

Scientists keep coming back to find out more about this fascinatingly chilly object

1 CENTRAL STAR

This composite image of the Boomerang Nebula shows the central star as a glowing-white object. It's ejecting material ten times faster than normal, at around 164 kilometres (102 miles) per second.

2 A FAR STRETCH

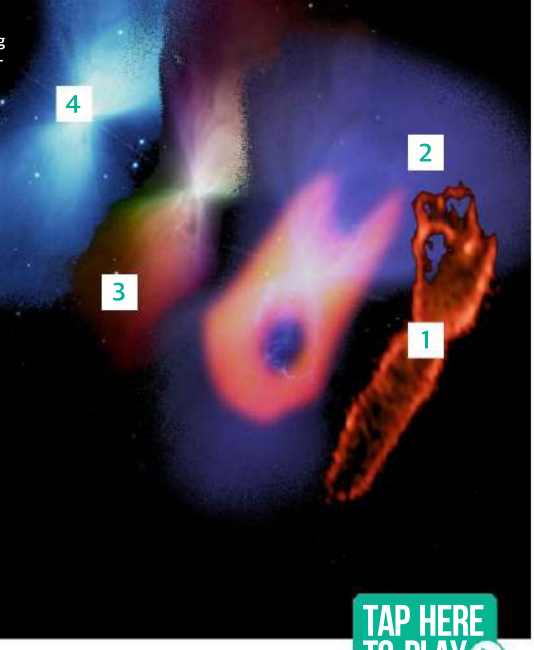
The jet fired by the star produces an hourglass outflow that actually stretches more than 3 trillion kilometres (1.8 trillion miles). It takes 3,500 years for material to reach these extreme distances.

3 THE HOURGLASS SHAPE

The hourglass shape is a trick of light, only appearing because of bright carbon monoxide molecules within the inner outflow of cold gas and dust, as observed by ALMA.

4 AND THERE'S MORE

Wrapping the hourglass outflow is a roughly round ultracold outflow that is ten times larger, shown here in blue as taken by the Hubble Space Telescope. It means the shape isn't as boomerang-like as was first observed.



© NASA/ESA Hubble; ALMA

TAP HERE TO PLAY

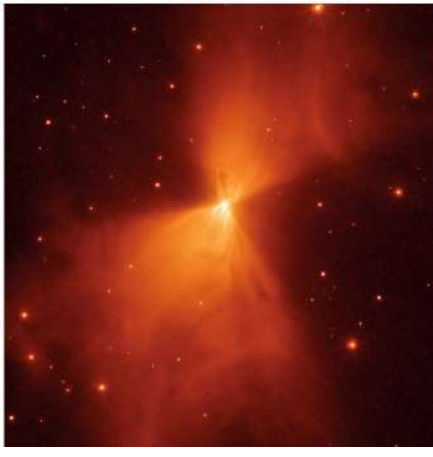
also rapidly expanding. This, he posed, would cause the temperature to drop dramatically, making it something of a cosmic refrigerator, and that it would lead to some spots in the universe being colder than the background temperature.

In 1995, Sahai, along with Lars-Åke Nyman of the European Southern Observatory and Onsala Space Observatory, Sweden, used the Swedish-ESO Submillimetre Telescope in Chile, which was decommissioned in 2003, to test his theory on the Boomerang Nebula. Several observations were taken between August and October that year, with signals from the carbon monoxide in the Boomerang Nebula being compared to signals from the cosmic microwave background (CMB) left over from the Big Bang.

It was discovered that the Boomerang Nebula is so cold that it was – as Sahai predicted – even lower than the temperature of the CMB, which is -270.4 degrees Celsius (-454.7 degrees Fahrenheit). Indeed, some of the CMB's light was found to be absorbed by the Boomerang Nebula. It led to the published conclusion in 1997 that the Boomerang Nebula was the coolest spot in the universe. The next question, however, was why this expanding nebulae was so much colder than others.

Sahai looked to resolve this puzzle, and the quest for a solution has taken a few twists and turns over the years. Faced with a star much like our Sun, shedding its outer layers as expected during the last stages of its life, it was clear the Boomerang Nebula's expanding gas was seen to be cooling very efficiently, making it extremely chilly. Sahai came up with the theory that this was because it was losing its mass about 100 times faster than other similar dying stars.

What's more, he said it was doing so a jaw-dropping 100 billion times faster than Earth's



Source: Wikipedia Commons © Judy Schmidt

Sun. As if to add to the jaw-dropping list of facts, NASA says this has actually resulted in nearly one-and-a-half times the mass of our Sun being lost by Boomerang Nebula's central star over the past 1,500 years. This was thought to be due to an ejection process known as bipolar outflow, and since the gases are being thrown off so fast – at 164 kilometres (101 miles) per second – it was said to be blasting away a lot of heat energy.

"Dying stars, like the one which produced the Boomerang Nebula, play a vital role in creating Solar Systems like ours," said Sahai at the time. "As these stars die, they synthesise and scatter elements like carbon and nitrogen and dust particles which sow the seeds for the birth of new suns, planets and life."

How this would work is perhaps best explained by blowing on your hand. Take a deep breath, place your hand in front of you and with your mouth open wide, start to exhale. It feels warm, doesn't it? Now let's repeat this by taking a deep breath one more time. Instead of keeping your mouth open, bring your lips together so that you exhale through a small hole. Suddenly, it feels much cooler.

This is what scientists thought the Boomerang Nebula was doing: rapidly blowing off a lot of gas through two small openings. Just as when air leaves your puckered lips, the nebula's gas expands and the molecules separate, mixing with the cooler molecules around them. It draws on the energy of those surrounding molecules and creates colder air.

Yet to be sure that the Boomerang Nebula really is as cold as it's believed to be, there have been further studies, and they've been throwing extra light on this freezing region. In 2013, for instance, Sahai once again led research into the preplanetary nebula, this time using the Atacama Large Millimeter/submillimeter Array

THE ATACAMA LARGE MILLIMETER/SUBMILLIMETER ARRAY

1 HIGH PRECISION

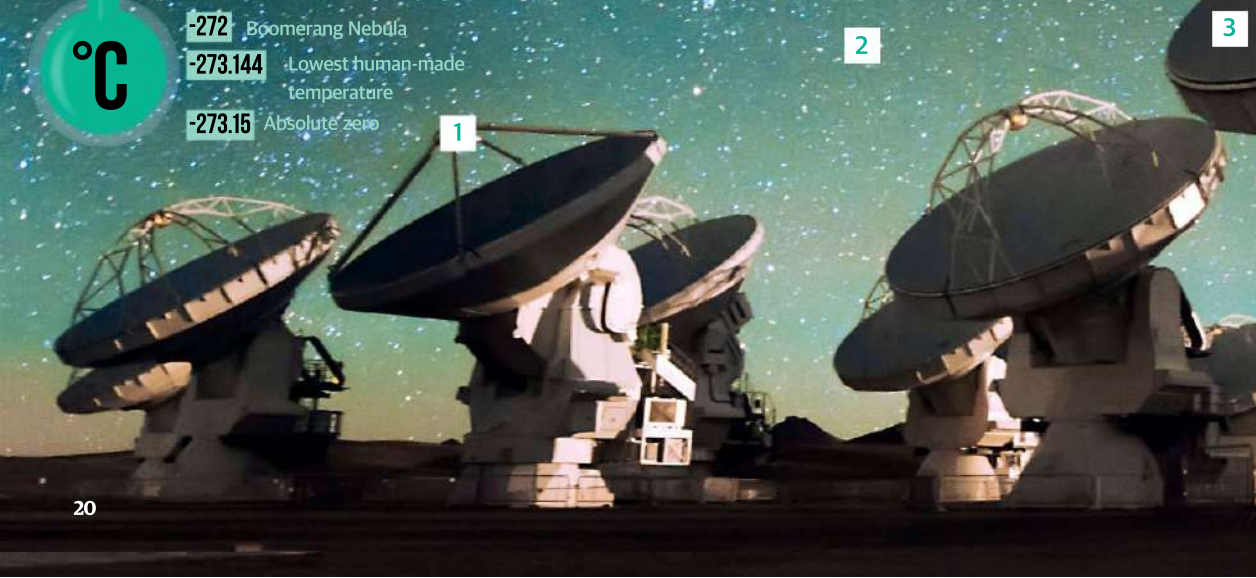
ALMA is made up of 66 high-precision antennae, operating at wavelengths of 0.32 to 3.6 metres (1.0 to 11.8 feet). The main array is made up of 50 antennae, each measuring 12 metres (39.4 feet) in diameter. The array boasts a sensitivity ten times sharper than Hubble.

2 MAKING THE INVISIBLE VISIBLE

Being able to observe in submillimetre wavelengths allows ALMA to build a picture of some of the coldest objects in the universe.

3 ALMA'S AIMS

Using data from ALMA, astronomers are able to peer into the chemical and physical conditions of dense clouds of gas and dust. The array is also able to collect light from some of the earliest and most distant galaxies.



(ALMA) in Chile. It confirmed the temperature and added some fresh evidence.

First, it showed that the nebula wasn't quite as boomerang shaped as it looked when observed using ground-based telescopes. This actually backed previous observations using the Hubble Space Telescope, which had shown it to resemble a bow tie, but the ALMA images depicted a more ghost-like scene.

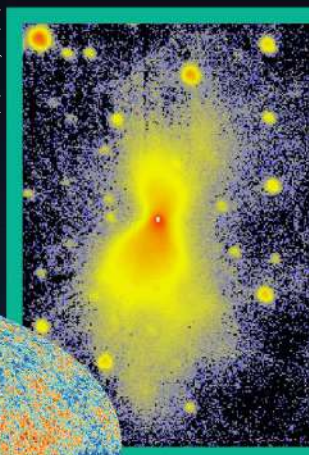
"What seemed like a double lobe, or 'boomerang' shape, from Earth-based optical telescopes is actually a much broader structure that is expanding rapidly into space," said Sahai at the time. This would be in line with most planetary nebulae, and as Sahai has pointed out, when astronomers looked at the Boomerang Nebula with Hubble in 2003, they did indeed see a classic 'hourglass' shape.

"Many planetary nebulae have this same double-lobe appearance, which is the result of streams of high-speed gas being jettisoned from the star," Sahai commented. "The jets then excavate holes in a surrounding cloud of gas that was ejected by the star even earlier in its lifetime as a red giant."

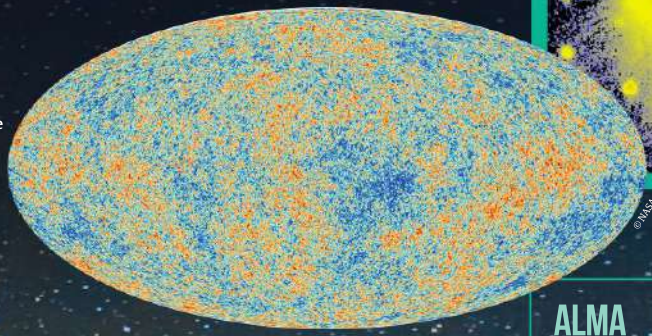
During observations made prior to 2003 using single-dish millimetre-wavelength telescopes, however, astronomers weren't seeing the double lobe. Instead astronomers found that the Boomerang Nebula was shown to be more uniform and near-spherical. With

Right: This false-colour image shows a cold wind blowing from the central star

Below: The CMB is leftover radiation from the Big Bang



© R.Sahai (JPL) and L. Nyman (ESO)



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ALMA

Name: The Atacama Large Millimeter/submillimeter Array

Site: Chajnantor Plateau, Chilean Andes

Type: Submillimetre interferometer array

Altitude: 4.6 to 5.0 kilometres (2.8 to 3.1 miles)

First light: 30 September 2011

4 HIGH UP IN THE ANDES

The ALMA site has been built on a five-kilometre (three-mile) plateau, where conditions are dry – this ensures that the array is able to pick up the millimetre and submillimetre wavelengths that would otherwise be absorbed by water vapour in Earth's atmosphere.

4

© Alamy

ALMA, however, they were able to observe the distribution of carbon monoxide molecules glowing brightly at millimetre wavelengths and the double-lobe structure became apparent, albeit in the nebula's inner regions.

What was described as a 'dense lane of millimetre-sized dust grains surrounding the star' also explained why the outer cloud had an hourglass shape in visible light. The National Radio Astronomy Observatory said: "The dust grains have created a mask that shades a portion of the central star and allows its light to leak out only in narrow but opposite directions into the cloud, giving it an hourglass appearance."

It was a breakthrough. "This is important for the understanding of how stars die and become planetary nebulae," said Sahai. "Using ALMA, we were able to shed new light on the death throes of a Sun-like star." And yet the research hasn't stopped there. In 2017, Sahai – who currently works at NASA's Jet Propulsion Laboratory in Pasadena, California – looked to address why so much matter was being ejected. The potential answer was that a small companion star could have plunged into the red giant. Thanks to ALMA, astronomers could finally start to calculate the Boomerang Nebula's age, mass, kinetic energy and extent.

"New data shows us that most of the stellar envelope from the massive red giant star has been blasted out into space at speeds far beyond the capabilities of a single red giant star," Sahai said. "The only way to eject so much mass and at such extreme speeds is from the gravitational energy of two interacting stars, which would explain the puzzling properties of the ultracold outflow."

The next step for scientists will be to find similar phenomena that could be ever colder still. As Nyman, an astronomer at the Joint ALMA Observatory in Santiago, Chile, and coauthor on the 2017 paper noted: "It's possible these super cosmic freezers are quite common in the universe but they can only maintain such extreme temperatures for a relatively short time."

Astronomers are already seeing a slow warming of the Boomerang Nebula, and they consider themselves fortunate to have been able to observe the object during such a short-lived period of its life. Eventually, the Boomerang Nebula's central star will become a white dwarf, the destiny of all planetary nebula progenitors. Unfortunately, due to great mass loss which has already been ongoing for many centuries, this curious spot in the night sky will not be the coldest place in the universe forever. What will take its place, however, remains a mystery.

David Crookes
Science and technology journalist
David has been reporting on space, science and technology for many years, has contributed to many books and is a producer for BBC Radio 5 Live.

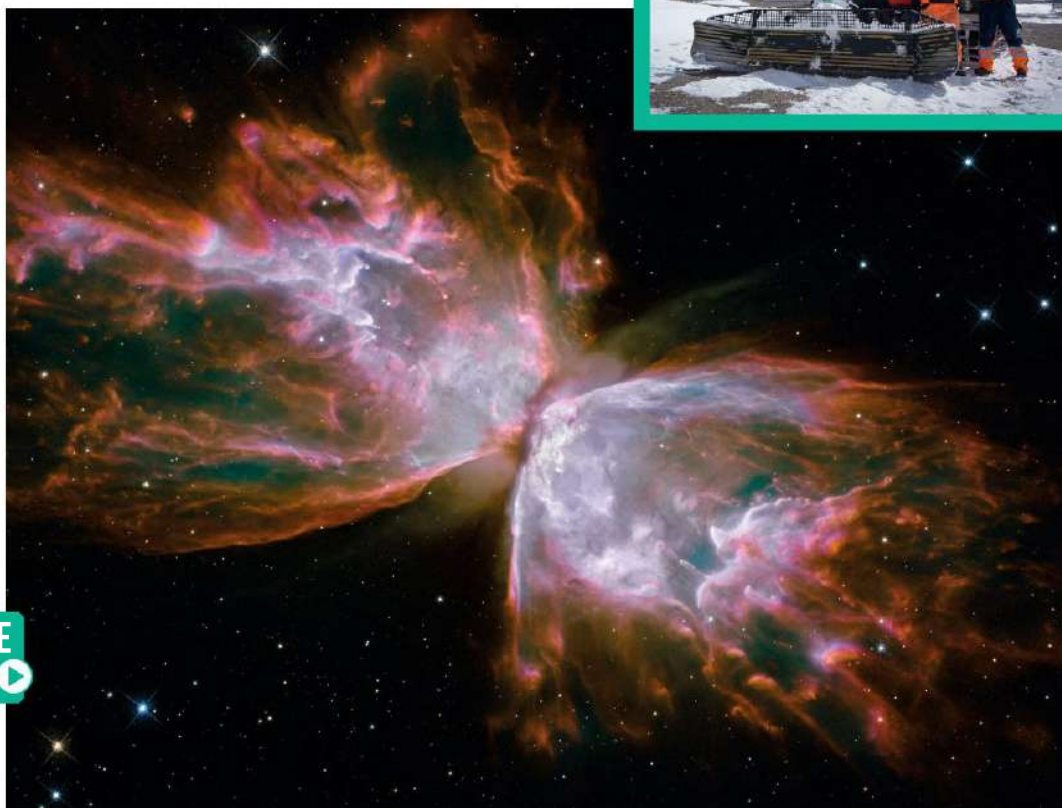
"NEW DATA SHOWS US THAT MOST OF THE STELLAR ENVELOPE FROM THE MASSIVE RED GIANT STAR HAS BEEN BLASTED OUT INTO SPACE"

RAGHVENDRA SAHAI

© ESO

Right: The Butterfly Nebula exhibits a similar bipolar structure to the Boomerang

Far right: The Snowcat clears the way to ALMA's antennae



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TAP HERE TO PLAY

CELESTRON

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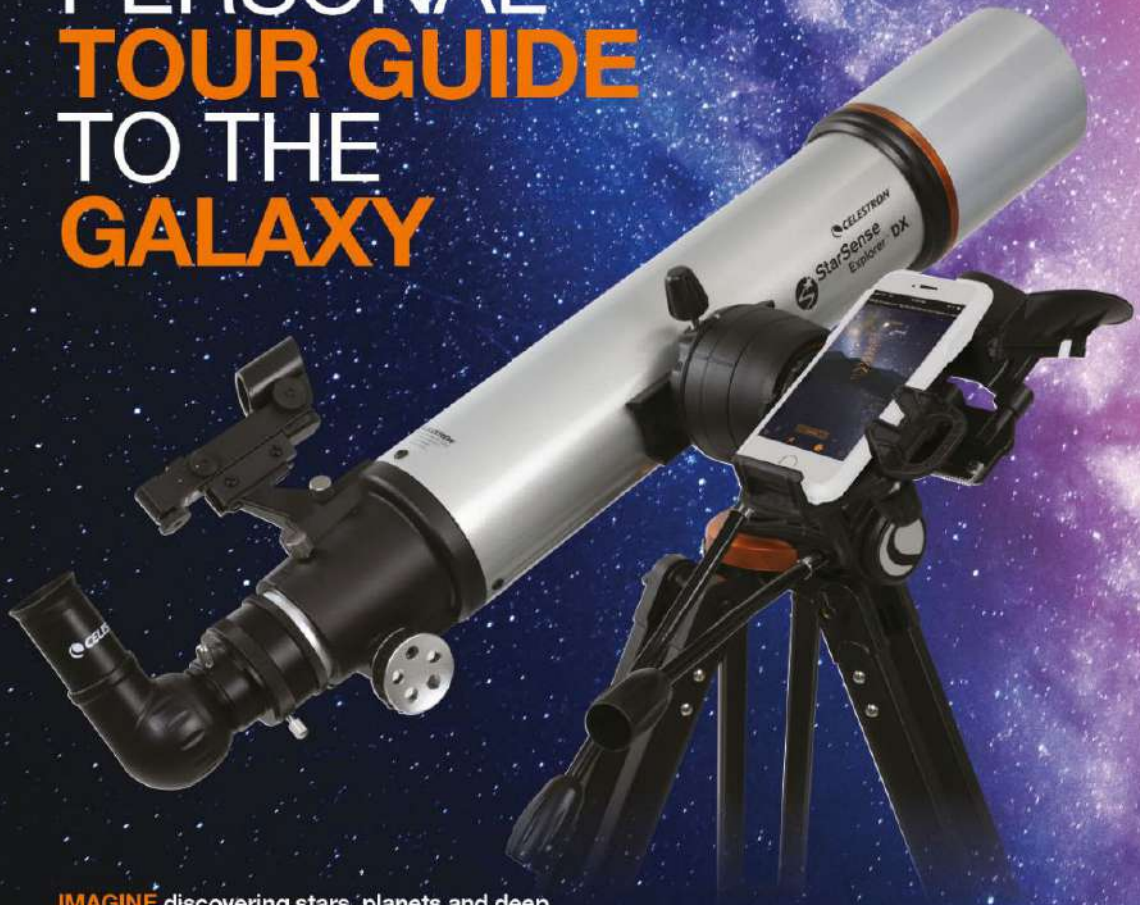

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SPACE ELEVATOR

Launching into space is a hazardous process. Wouldn't it be simpler if we could take a lift?

A space elevator is the idea of building a lift connecting the ground to Earth orbit. The first person to consider it was Konstantin Tsiolkovsky, who was also the first to set out the equations that govern orbital rocket launches. In 1895 he was inspired by the new Eiffel Tower, pointing out that if such a tower could be built 35,800 kilometres (22,245 miles) tall, you could go to space just by taking the lift up the tower. To appreciate why – and why this distance – we must consider how orbits work.

When spacecraft launch into space, they don't just pass out of the atmosphere and start floating. Getting past the atmosphere is fairly easy; the boundary of space is only 100 kilometres (62 miles) up. To be in orbit, a craft has to be travelling fast enough horizontally – about eight kilometres (five miles) per second – that the tendency to be flung away from Earth is balanced by the gravity trying to pull it back down, so that it continuously circles Earth. The higher the orbit, the faster the spacecraft must travel, and the longer it takes to orbit. 35,800 kilometres (22,245 miles) high is an orbit called 'geostationary' (GEO). In GEO it takes 24 hours to make one orbit, so spacecraft appear to hover over the same spot on Earth – this is used for satellite TV so you get continuous signal.

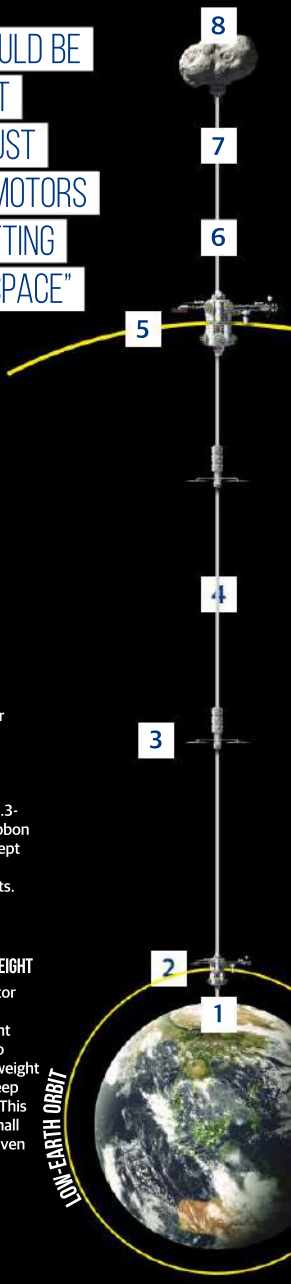
Travelling on a space elevator, you would slowly gain both the height and speed required to be in GEO at the top. There would be no violent launch or highly stressed rocket engines, just electric motors gently lifting you into space over the course of a few days – it would be the same as taking a train 90 per cent of the distance around the world. But we can't build a tower that tall, as no material comes close to supporting its own weight at such a height. But in 1959, another Russian scientist, Yuri Artsutanov, suggested that it might be possible to build such a structure if it was a cable in tension, rather than a tower in compression.

In this case, a satellite is deployed in GEO and begins to wind a tether downwards, while another tether winds outwards with a counterweight on the end. Ultimately, the first tether touches down on Earth where it can be anchored, while the counterweight, being flung outwards by the rotation of the system, balances the weight of the tether – plus some spare capacity for the weight of the elevator cars moving on it.

The concept was considered science fiction for many years, however, as no materials came close to the strength needed. That changed in the 1990s with the discovery of carbon nanotubes – cylindrical molecules of carbon that would be strong enough, if we can make them long enough. A NASA study from 2000 proposed that a small 20-tonne nanotube tether could be launched and installed from GEO. It would be anchored to a floating platform, then small robotic climbers would run up adding more material. This would build a one-metre (3.3-foot) wide tether, thinner than a sheet of paper but still extremely capable of lifting climbers.

Unfortunately, no one has made nanotubes longer than 50 centimetres (19.7 inches). But a number of organisations are working towards space elevators. US-based company LiftPort Group is developing a commercial carbon nanotube business in support of these plans, and intends to build a space elevator headed for the Moon with existing materials. If all goes to plan, we may even see a railway to the sky before the second half of this century.

"THERE WOULD BE NO VIOLENT LAUNCH, JUST ELECTRIC MOTORS GENTLY LIFTING YOU INTO SPACE"



1 EQUATOR
The space elevator would be attached at the Earth's equator so the tether would stay aligned above its base.

2 LOW-EARTH ORBIT STATION
A space elevator could provide cheap access to low-Earth orbit. By some estimates it would only cost around £74 ($100) per kilogram to ferry cargo by tether.

3 CLIMBER
The carriages, or climbers, would be electrically powered, either via the tether itself or photovoltaic panels lit by ground-based lasers.

4 TETHER
The tether will be made from carbon nanotubes – most likely a one-metre (3.3-foot) wide ribbon to better accept small space debris impacts.

5 GEO ORBIT
In this orbit, it takes 24 hours to go around Earth. Spacecraft match the spin of our planet, appearing to hover over the same place.

6 CENTRE OF MASS
The centre of mass of the whole system must be above GEO so that the tether is always stretched out in tension.

7 ESCAPE VELOCITY
In some designs, the tether extends well beyond GEO – in one case three times further. Payloads at the end would be flung away from Earth completely.

8 COUNTERWEIGHT
The elevator must have a counterweight above GEO to balance the weight below and keep it in tension. This could be a small asteroid, or even more tether.

RIDING THE ELEVATOR

The tether provides a physical link for climbers to journey into space. Most likely the tether will be a ribbon shape, and the climbers will simply clamp on and drive up it with rollers. Power could be provided through a carbon tether from solar panels on the counterweight, or solar panels lit by ground-based lasers. The climbers would travel at about 200 kilometres (124 miles) per hour, taking 7.5 days to reach GEO, making for a very different launch experience.

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INTERVIEW

BIO

Victor Glover

Glover is a NASA astronaut and naval aviator. In his first spaceflight mission, he served as a pilot on the Crew-1 flight of SpaceX's Crew Dragon, which launched on 15 November 2020. Crew-1 was the first commercial crewed mission to the International Space Station (ISS) and the second flight overall after SpaceX's Demo-2 test mission, which launched in May 2020.

Glover became the 15th Black astronaut in space and the first Black astronaut to stay for an extended period on the ISS. Glover launched to the ISS at a time when many were forced to isolate due to the pandemic and returned to a world where vaccines had begun rolling out.

© NASA

NASA ASTRONAUT VICTOR GLOVER

"BEING IN SPACE IS LIKE LIVING A DREAM"

Serving as a pilot on SpaceX's Crew Dragon capsule, the astronaut reveals the most scary thought that's entered his head, his thoughts on spacewalking and returning to Earth during a pandemic

Interviewed by Lloyd Coombes

Is there a particular psychological profile that suits an astronaut?
There is, absolutely. We have psychiatrists and psychologists that are part of our selection process and are part of the maintenance of our health and wellbeing for astronauts; they're here annually. And while you're in space that's a very important part of your mission support team.

But what does it take to be the man that was spacewalking earlier this year?
There are just things about living in what we call the ICE environment – isolated, confined, extreme environments. People who winter over in Antarctica, people who live on submarines or deploy in our military out into the middle of nowhere, living in tents for months on end, fighting in combat. Those things require a certain type of mentality – you've got to have mettle.

There's a lot of NASA research into resilience and how to quantify it, how to find it when looking for candidates, but also in your workforce that you have. How do you instil it? What things do you do to highlight it and then reinforce it? That's a big one. There are probably lots of other things, but I would say that is one of the most important. Resilience is a big part of it.

It sounds like a huge part of being a successful astronaut is a sense of adaptability. You have an impressive history, and we know that you became an astronaut following military service. Do you feel this helped with your astronaut training?
We all come from these various walks of life – science, engineering, education, the military – and we bring these skills from all parts of, you know, all types of professions. But at the end of the day, it's not what you used to do that's going to make you successful here. It's what you're able to adapt to, what you're able to become, no matter what you did before. It's not going to be enough to make you a successful astronaut, so you really have to stretch personally and professionally.

I think that resilience, adaptability and flexibility are very important. And having a healthy sense of humour, being able to just kind of laugh at things. You're going to make mistakes. Your colleagues are going to make mistakes. And if you can have a laugh at yourself, that perspective is healthy.

Spaceflight has been part of humanity for decades now, but we're still some way off it being commonplace, despite recent advances. How much of a fear of the unknown is there with even the most 'standard' missions?
I think that first of all, there's no such thing as a standard mission. As soon as we start believing

© NASA

Right: Glover celebrated his birthday while aboard the ISS

© NASA

© SpaceX

Above: Glover during a spacewalk to ready the ISS truss structure for solar array upgrades

Left: Glover launched to the ISS on the SpaceX Crew-1 mission

and treating things like they are standard in this business, we've taken the first step and lined up what's going to go in the mishap report - we were complacent.

There are no standard missions. I think understanding that is one of the things that permeates the way we train and the way we operate and fly the space station. And soon these lunar Artemis missions, even though they'll be shorter, will receive the scrutiny they deserve because they're so unique.

Sending humans into space will never be commonplace, even right now with what's going on in the world. We're looking at William Shatner flying to space. That's amazing, but that's not commonplace. More of that won't make it commonplace; it will still be unique. And there's the unknown, you know? I think that's one of the reasons that education and training are so important. There's no way to always make the unknown known. But you prepare for the unknown with a solid foundation of education.

You have enough tools that you can use in a given situation so that when you face the unknown, you make one decision at a time. You do one thing at a time and you just keep working on that problem. Fear is when you're not prepared. We respect the environment we're going into, but I wouldn't use the term fear. We've done all the preparation we can, which emotionally desensitises you so you can focus on your tasks.

What's the most frightening thought that's running through your mind ahead of launch? And what's the most frightening thought when heading into space?

The most frightening thought for me was that this could go badly and I could not come back. I've thought about that. I've been deployed in combat before, so I thought about it even before trying to hurl off the planet, at least for a really extended period of time. But it was the fact that my family was right there, like my parents, my wife, and that it's also so public that that part would be a challenge for my family. The hardest part for me was just knowing that if something happened, they would be dealing with it without me. Not in terms of like I was Superman and going to swoop in and save them, but just that they were going to have to figure it out.

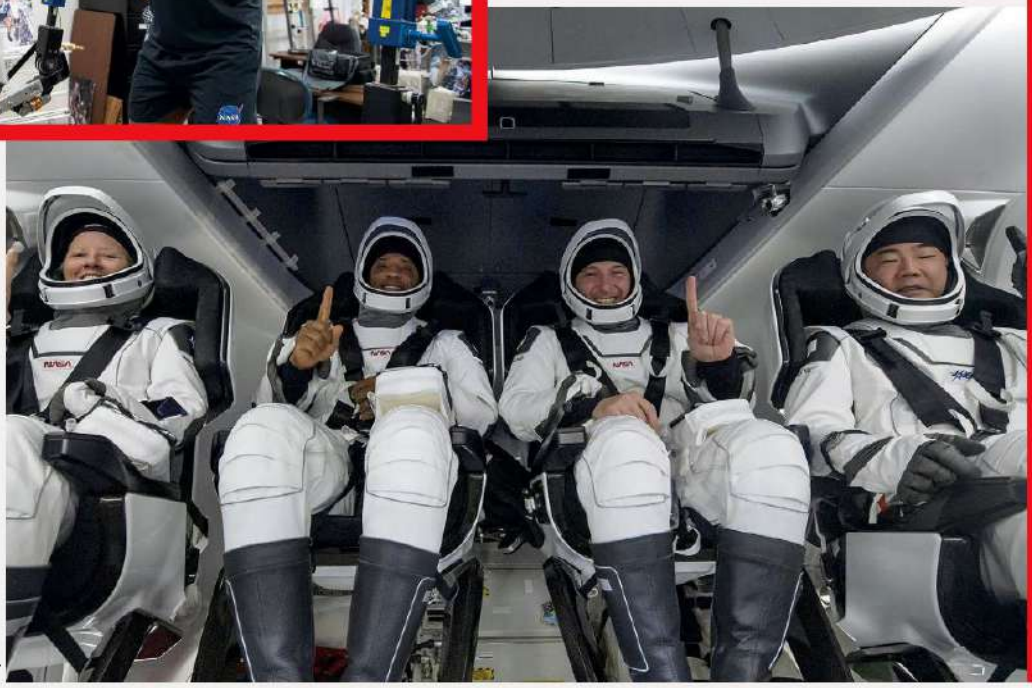
Hurling skyward on top of high explosives, as crazy as it sounds, was awesome. A lot of it was unknown. It was my first time flying into space, but I had things to focus on. I had to do the thing I was trained to do, which put things in a great perspective – for me it was fun, even though it was unknown.

What about coming back? How does life change when you go from the ISS and come back to Earth? After an astronaut has been to space, is there a mental 'hangover' associated with having achieved what so many never will and the relative mundanity of life back on Earth?
Coming back from space can really be disorienting, literally and figuratively. We launched in a pandemic and there were no vaccines. We came back and there are vaccines, and we're still figuring it out and working our way through that. Likewise, I landed and my eldest daughter graduated from high school, and that was great. I just fell into that. We wanted to celebrate her, and we had the transition of getting her to college, but it took my mind off 'wow, I'm back on Earth'. That's just one experience. Had I landed last year, while the pandemic was in full swing, I think in a world where you want to be closer to people, having been in space, that could've been really disorienting.

Being in space is like living a dream – you can float, you can lift heavy things. And then coming back to Earth, it's like a concentrated, extra-strong dose of reality. But looking at Earth from space, as beautiful as it was, it was a reminder that, next to my crewmates, everything I love is down on Earth – so I tried to make the most of being in space. I did everything up there I wanted to do so that when I came back, I had closure. Coming back to Earth really felt like what I needed at the time. I wouldn't call it a hangover – it was just great to be back home and see my girls and my dog.

© NASA

> "IT'S NOT WHAT YOU USED TO DO. IT'S WHAT YOU'RE ABLE TO ADAPT TO, WHAT YOU'RE ABLE TO BECOME"



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Above: Glover working out with the Advanced Resistive Exercise Device (ARED) at Johnson Space Center

Right: NASA astronauts Shannon Walker, Glover and Mike Hopkins and Japan Aerospace Exploration Agency (JAXA) astronaut Soichi Noguchi

JUPITER'S GREAT RED SPOT IS DEEPER THAN SCIENTISTS THOUGHT

The storm system isn't just wide... it also has incredible

Reported by Rahul Rao

It's hard to imagine the sheer scale of Jupiter's Great Red Spot from Earth; the storm is so big that it could swallow our planet. But it turns out that the Great Red Spot isn't just wide - it's deep too, quite a bit deeper than anybody expected. Data from NASA's Juno has shown that the behemoth storm extends as much as 500 kilometres (310 miles) beneath Jupiter's cloud tops. And the Jovian maelstrom is linked to jets that go far deeper, hinting that the giant planet's upper and lower atmospheres are tied together.

The findings come from two groups of scientists, who analysed data gathered by two different Juno instruments. One group measured the Great Red Spot's gravity. It began as a simple idea to turn Juno's Gravity Science instrument on the storm in order to see if it left behind any fingerprints on Jupiter's gravitational field. "This wasn't part of the original Juno proposal," said Marzia Parisi, a scientist at NASA's Jet Propulsion Laboratory in Southern California, who led the study that reported the gravity results.

Using gravity measurements to investigate atmospheric phenomena isn't new. It's been done on Earth by the twin satellites of NASA's Gravity Recovery and Climate Experiment (GRACE). Gravity instruments can also see deeper into the atmosphere than others tend to see. This had just never been done with the Great Red Spot.

But even after the idea was approved, Parisi and her colleagues had no idea if they would actually find anything. The Great Red Spot might be a colossus, but it's a drop in the bucket of Jupiter's total mass. "If you don't know how deep the Great Red Spot is, you can't predict what you're going to see," she explained.

But the researchers did indeed pick up fluctuations in Jupiter's gravitational field, enough for them to get a handle on the storm's depth: 500 kilometres (310 miles), more than the distance from sea level to the International Space Station. And the great storm seems to be fed by jets that reach down far deeper - as much as 3,000 kilometres (1,900 miles).

x2 Images © Getty

At the same time, a different group of researchers was studying the Great Red Spot with Juno's Microwave Radiometer, an instrument that probes the planet's atmosphere with microwaves. These scientists wanted to look deep into the storm vertically to see how it ticked.

They found that the Great Red Spot, along with several other storms on Jupiter, stretches far down, with precipitation and drafts at unprecedented depths. They found signatures of these phenomena below Jupiter's cloud level, beneath which the ammonia and water in the atmosphere are expected to condense. Together, the gravity and microwave measurements hint that Jupiter's upper atmosphere is meaningfully connected to these depths.

Juno has been making long, looping orbits around Jupiter since 2016, and NASA recently extended its mission until 2025. Soon, if all goes according to plan, Juno's orbital path will move to take the probe over the planet's north pole – away from the Great Red Spot, which is farther south. But according to Parisi, Juno's instruments will get the chance to watch other curiosities, such as Jupiter's cryptic polar cyclones. "And then we have the moons," said Parisi. "We flew by Ganymede already, and we're going to do that for Europa and Io. They're obviously going to collect data there as well."

THE FORTHCOMING YEAR IS SET TO BE AN IMPORTANT ONE FOR SPACE EXPLORATION AND ASTRONOMY
SPACE EVENTS
2022

© Getty

Reported by Robert Lea

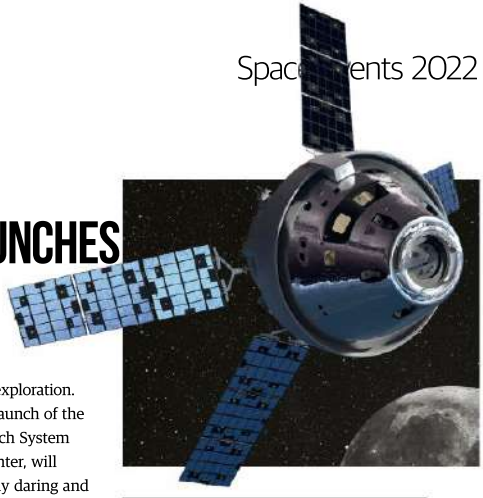
The last 12 months have seen some pretty impressive space-related events and discoveries. The commercial space race kicked into high gear with flights by Virgin Galactic, Blue Origin and SpaceX, the latter of which launched the first all-civilian crew to low-Earth orbit. Even *Star Trek* actor William Shatner got in on the act, swapping the Starship Enterprise for Blue Origin's New Shepard.

In the last month of 2021, the James Webb Space Telescope should have finally launched, kick-starting a new era of discovery, yet even before this new space telescope starts examining the atmospheres of exoplanets, researchers may have made history by discovering the first planet ever found outside the Milky Way.

2022 will pick up the baton from 2021, building on the groundwork laid this year. While it's difficult to predict what we will discover in the forthcoming 12 months, we can look ahead to the scheduled launches, science tests and astronomical events. This includes our continuing exploration of Mars – scouring our neighbour for signs that life may once have existed on or below its surface – flybys of the moons of Jupiter and our return to the lunar surface.

FEBRUARY

ARTEMIS 1 LAUNCHES FIRST FLIGHT



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AR SCAN HERE

In February, Artemis 1 will hopefully begin its work, signifying an important step for human space exploration. The first mission of the project, the launch of the Orion spacecraft and the Space Launch System (SLS) rocket from Kennedy Space Center, will mark the beginning of an increasingly daring and groundbreaking series of deep-space missions.

Launching from the most powerful rocket in the world, the uncrewed craft Orion will journey further into space than any craft designed to carry humans ever has before. The three-week mission, set to begin on 12 February, will see it travel 450,000 kilometres (280,000 miles) from Earth. This will become the longest mission a spacecraft designed to be crewed has undertaken without docking at a space station, setting the scene for future missions.

Artemis won't just be breaking new ground in space. Not only does the program aim to deliver the next humans to the Moon in 2024, but these voyagers will include the first woman and the first person of colour to step onto the lunar surface – a giant step for diversity and the first step to the first human-crewed mission to Mars.

FEBRUARY

LUNAR ICECUBE HUNTS FOR WATER ON THE MOON

Launching along with Artemis 1 is the ride-along CubeSat mission Lunar IceCube. The aim of this mission is to study the distribution of water and organic volatiles on the Moon as they evaporate throughout the day. This will help us assess how much lunar water is in the form of liquid, ice or vapour.

From these observations, scientists will become better positioned to understand the current dynamics of volatile sources, sinks and processes on the Moon. They can then work backwards and search for the evolutionary origin of volatiles – compounds that evaporate – on Earth's natural satellite. Lunar IceCube will do this from a high-angle elliptical orbit around the Moon. As the mission is a short-term one, only scheduled to last six months, it likely won't see past the close of 2022.

"THIS WILL HELP US ASSESS HOW MUCH LUNAR WATER IS IN THE FORM OF LIQUID"

© Morehead State University

FEBRUARY AND SEPTEMBER

THE JUNO MISSION TURNS ITS ATTENTION TO JUPITER'S MOONS

The Juno mission caused a stir in 2021 when it revealed more in-depth observations of the Solar System's largest planet, Jupiter, than ever before. The satellite's findings regarding the gas giant's atmosphere allowed scientists to calculate the depth of Jupiter's Great Red Spot – the Solar System's largest storm. Juno's mission will continue throughout 2022 and until at least 2025, with two events in the mission's near future that are particularly exciting.

Within the next 12 months, Juno will pass close to the surface of the Jovian moon Europa twice. The spacecraft will first orbit Europa in February, when it passes the moon at a distance of around 46,600 kilometres (29,000 miles). Later in 2022, the spacecraft will sweep much closer to the Jovian moon. Juno's September passage of the icy moon will bring it within 350 kilometres (221 miles) of Europa's surface. Close observations of this Jovian moon are particularly exciting, as it has demonstrated evidence that beneath its icy shell lurks liquid-water oceans. During these passages, Juno could catch further evidence of these oceans on Europa, setting up NASA's forthcoming Europa Clipper mission to the Jovian system, which could reveal if Europa also hosts the conditions needed for life.

MAY

MARS AND JUPITER IN CONJUNCTION

In astronomy, a conjunction occurs when any two astronomical bodies, such as asteroids, moons and planets, appear to be close together in the sky over Earth. The effect is caused by the bodies' orbits around the Sun, and even though they appear closer in the sky, they could still be millions of miles apart. There are far too many conjunctions during the next year than can be listed here, but one of the next 12 months' more significant conjunctions will be that of Mars and Jupiter on 29 May. The two planets will share the same right ascension in the sky and will also make a close approach at this time. While they won't be close enough to glimpse together by telescope, the planets will be visible together with the naked eye or in a pair of binoculars.

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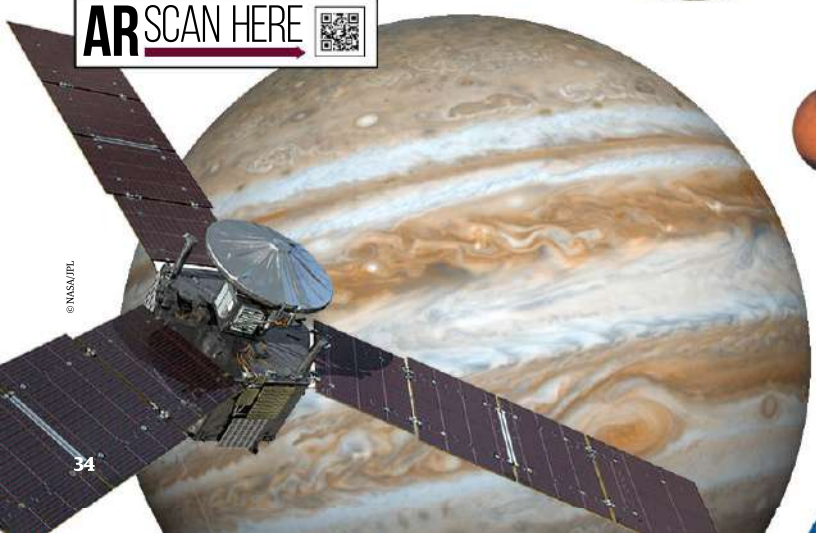

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APRIL

DIVERSITY ABOARD THE ISS

In April, SpaceX's crew Dragon will carry its fourth team to the International Space Station (ISS), a mission that will be an important one for diversity in space exploration. Among the team's crew is mission specialist Jessica Watkins, who will become the first black woman to travel to the ISS.

Watkins was accepted for NASA's astronaut training program in 2017 and completed her training in 2019. This will be her first space mission, but Watkins is no stranger to NASA missions after completing stints at the agency's Mars Desert Research Station, near Hanksville, Utah, and its Aquarius Reef Base, located off Key Largo in the Florida Keys National Marine Sanctuary.

The SpaceX Crew-4 mission to the ISS is set to launch from NASA's Kennedy Space Center in April 2022. Alongside Watkins will be fellow NASA astronauts Kjell Lindgren and Robert Hines and European Space Agency (ESA) astronaut Samantha Cristoforetti. The team's six-month mission will involve work in the microgravity laboratory of the ISS.

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MAY TO JUNE

WEBB BEGINS ITS SCIENCE MISSION

The first half of 2022 is going to be a busy one for Webb. After its launch from French Guiana in December 2021, the space telescope will settle into its orbital position above Earth at the stable Lagrangian point L2. Around January 2022, Webb's primary mirrors will begin the process of alignment. This will form the telescope's 6.5-metre (21.3-foot) primary mirror. Tests will then commence, seeing how well these mirrors work as a single surface. Between May and June is when the really exciting stuff begins for Webb, as this is when it will begin science operations.

Webb will allow astronomers to see further back in time than ever before. Researchers will finally be able to observe the first galaxies and stars, seeing what the universe looked like as early as 100 million years after the Big Bang. Webb will also observe the effects of dark energy as it drives the accelerating expansion of the universe. The use of infrared to observe the cosmos will also help peer through the dense clouds of gas and dust that are home to star formation. This will give scientists a better idea of the processes that lead to the birth of stars and planets. Webb will also be peering into the atmospheres of exoplanets, assessing their compositions and potentially detecting the building blocks needed for life.

MAY

2009 JF1 HIT OR MISS

Not seen in our skies since 2009, on 6 May 2022 this near-Earth asteroid will pass within about 75 million kilometres (46.6 million miles) of Earth. There's a chance that this small asteroid, about 13 metres (42.6 feet) in diameter, could actually strike the Earth. That chance is pretty small though, about 1 in 3,800 or around 0.026 per cent, and even if the asteroid were to enter the planet's atmosphere, it likely wouldn't reach the surface.

Travelling at about 26.39 kilometres (16.4 miles) per second, the asteroid is moving faster than the Chelyabinsk meteor, an asteroid with a diameter of 17 metres (55.7 feet) which exploded about 25 kilometres (16 miles) over Russia in February 2013. The so-called 'sky burst' released as much energy as was yielded by the atomic bomb that devastated Hiroshima. Over 7,000 buildings were damaged in the blast, and around 1,500 people were injured. We can breathe a sigh of relief that there is a 99.974 per cent chance that 2009 JF1 will pass our planet without incident in 2022.

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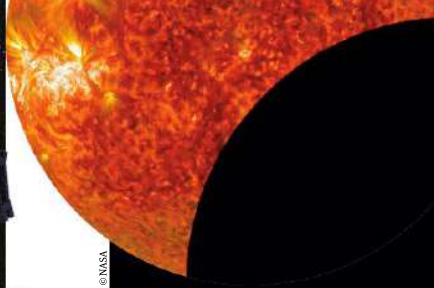

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ECLIPSES IN 2022

PARTIAL SOLAR ECLIPSE

30 April and 25 October

The next partial solar eclipse will occur on 30 April 2022 when the Moon passes in front of the Sun, resulting in a partial eclipse that will be visible from South America and Antarctica. A partial solar eclipse happens when the Moon comes between the Sun and Earth, but only partially covers the disc of the Sun. This is because the Moon, Sun and Earth aren't perfectly aligned, so only the outer part of the Moon's shadow falls on Earth. This has the effect of making the Sun look like a glowing orange cookie with a bite gouged out of it.

Partial solar eclipses happen between two and five times a year, meaning that in 2022 sky watchers will get a second chance to observe an event on 25 October. This second partial solar eclipse will be visible over most of Europe, northern Africa, the Middle East and Western Asia. Solar eclipses never come alone though, and both of these partial eclipses will be followed by lunar eclipses.

TOTAL LUNAR ECLIPSE

16 May and 8 November

In 2022 Earth will experience two total lunar eclipses. A lunar eclipse occurs when the Moon, Earth and the Sun align, but this time in such a way that the Earth is between the Sun and the Moon. As Earth's shadow falls over the Moon, the lunar surface reddens, caused by the fact that light from the Sun has to pass through Earth's atmosphere. This results in photons of red light being scattered by atoms in the atmosphere, known as Rayleigh scattering.

The first lunar eclipse of 2022 falls on 16 May and will be a blood Moon, so-called because of the Moon's red hue during the event. It will be visible over North America, South America, Europe, Africa and parts of Asia. The second total lunar eclipse of 2022 will happen on 8 November and will be visible over Australia, Asia, North America, parts of Europe and parts of South America.

© Nicholas Forder

SEPTEMBER

DART IMPACTS DIDYMOS

None of the over 27,000 near-Earth objects (NEOs) detected by NASA's Center for NEO Studies currently present a risk of impacting Earth, but that doesn't mean we should sit around and wait for a potential asteroid impact to start planning mitigation strategies. Launched in November 2021, NASA's Double Asteroid Redirection Test (DART) spacecraft will test a brute-force approach to the potential problem of an asteroid impact. In late September 2022, DART will complete its journey to the double asteroid system Dimorphos and Didymos. Once there, DART will slam into Dimorphos, the smaller of the two bodies, while travelling at a speed of around 24,000 kilometres (15,000 miles) per hour in an attempt to change the system's orbit. While this will be a nudge in cosmic terms, changing the orbit by just one per cent, NASA engineers will be watching closely to see if a kinetic impact like this is enough to save our planet from potential disaster.

"A BRUTE-FORCE APPROACH TO THE PROBLEM OF AN ASTEROID IMPACT"

EQUINOXES IN 2022

On the day of the equinox, the Sun shines directly down onto the planet's equator. The Earth's axis isn't tilted towards or away from the Sun at this point in the year. As a result, day and night are of almost equal length in almost all time zones. This happens twice a year and marks the beginning of spring or the beginning of autumn depending on which hemisphere an observer is in.

THE VERNAL EQUINOX

20 March

The first of this year's equinoxes, the vernal equinox falls on 20 March. The March equinox marks the point at which the Sun crosses an imaginary line in the sky over Earth, called the celestial equator, from south to north. For the Northern Hemisphere, the March equinox is the spring equinox and is considered by astronomers to mark the beginning of spring. For Southern Hemisphere residents, this marks the beginning of Autumn.

SUMMER SOLSTICE

21 June

June's solstice falls on the 21st. In the Northern Hemisphere, this event marks the point at which the imaginary pole extending out of the Northern Hemisphere tilts towards the Sun at an angle of 23.4 degrees. This means that the Sun is directly above the Tropic of Cancer in the Northern Hemisphere. As a result, the Southern Hemisphere is tilted away from the Sun. The June solstice marks the longest day north of the equator and the shortest day to its south.

© NASA

SOLSTICES IN 2022

If a year's two equinoxes are exemplified by equality in the days and nights of all time zones, then solstices are about disparities in these measures. During solstices, Earth's axis is either pointed towards or away from the Sun. This means that depending on what hemisphere you're in, you either experience the longest or the shortest day of the year.

SEPTEMBER EQUINOX

23 September

The second equinox of 2022, the autumnal equinox in the Northern Hemisphere, sees the opposite situation to the vernal equinox occur. Again the Sun is shining directly down onto the equator, but this time it crosses the celestial equator from north to south. Also reversed are the seasons. This equinox marks the astronomical beginning of autumn in the Northern Hemisphere and the beginning of spring in the Southern Hemisphere.

WINTER SOLSTICE

21 December

Instead of the imaginary pole extending out of the Northern Hemisphere pointing towards the Sun, it now points away. That means the Southern Hemisphere is pointing towards our star and receiving the lion's share of its heat and light. The December solstice marks the Northern Hemisphere's winter solstice and its shortest day, while it represents the Southern Hemisphere's summer solstice and its longest day.

METEOR SHOWERS

Just like every year, in 2022 Earth's sky will be lit up as meteors enter the atmosphere, their heating up causing a tail of hot air. The reason meteor showers occur regularly every year and that we can predict them is that they aren't visiting us, we are visiting them. As Earth orbits the Sun it passes through fields of debris left behind by comets on their elliptical journeys around our star. For instance, the Orionids, which Earth passes through in late October, are debris left behind by arguably the Solar System's most famous comet, Halley's Comet. Meteor showers don't take their name from the comet that sheds them, however, but from the constellation that they appear to be originating from during their peak.

QUADRANTIDS
28 December 2021 to 12 January 2022
Peak: 3 January
Meteors per hour at peak: 120
Constellation: Boötes

LYRIDS
16 to 25 April
Peak: 22 April
Meteors per hour at peak: 18
Constellation: Lyra

ETA AQUARIIDS
19 April to 28 May
Peak: 6 May
Meteors per hour at peak: 55
Constellation: Aquarius

DELTA AQUARIIDS
12 July to 23 August
Peak: 30 July
Meteors per hour at peak: 16
Constellation: Aquarius

PERSEIDS
17 July to 24 August
Peak: 12 August
Meteors per hour at peak: 100
Constellation: Perseus

DRACONIDS
6 to 10 October
Peak: 8 October
Meteors per hour at peak: 10
Constellation: Draco

TAURIDS
10 September to 20 November
Peak: 10 October
Meteors per hour at peak: 5
Constellation: Taurus

ORIONIDS
2 October to 7 November
Peak: 21 October
Meteors per hour at peak: 20
Constellation: Orion

LEONIDS
6 to 30 November
Peak: 17 November
Meteors per hour at peak: 15
Constellation: Leo

GEMINIDS
4 to 17 December
Peak: 14 December
Meteors per hour at peak: 120
Constellation: Gemini

URSIDS
17 to 26 December
Peak: 22 December
Meteors per hour at peak: 10
Constellation: Ursa Minor

SEPTEMBER TO OCTOBER

THE EXOMARS PROGRAM

Mars has become a hive of activity for space missions, and it's unsurprising that this will continue in 2022. Not only will the rovers Curiosity and Perseverance continue their fact-finding missions on the Martian surface, but in September the ExoMars Rover and Surface Platform are scheduled to join them. The rover, named Rosalind Franklin, and the Russian lander, dubbed Kazachok – which will serve as a surface platform for conducting science experiments – should arrive at the Red Planet nine months after launch.

The rover will carry the Mars Organic Molecule Analyser (MOMA), which will study organic molecules searching for the key building blocks of life spread across the Martian surface. The Rosalind Franklin rover will also drill down through the surface of Mars in search of organic molecules buried there and protected from the harsh solar radiation of the Sun.

© ESA

DECEMBER

NASA'S GIFT TO THE MOON

December is the perfect time to take stock of the past year and look ahead to the future. That is exactly what NASA aims to do with regards to Moon exploration when it launches the Polar Resources Ice Mining Experiment-1 (PRIME-1). Its aim is to drill near the south pole of the Moon to demonstrate the feasibility of mining for resources in future crewed lunar missions. In-situ resource utilisation will be a vital element for crewed space exploration, especially longer missions, in which one of the watchwords will be sustainability. In-situ resource management is important if current plans to make the Moon a stepping stone to the crewed exploration of Mars are to come to fruition. PRIME-1 is scheduled to launch on a Falcon 9 rocket from the NOVA-C landing platform developed by Intuitive Machines for lunar landing as part of NASA's Commercial Lunar Payload Services (CLPS) initiative.

© Intuitive Machines

AR SCAN HERE

Instant expert

WHY ARE WE STILL SEARCHING FOR INTELLIGENT ALIEN LIFE?

Should we widen our search criteria when looking for extraterrestrials?

Humans have long scanned the heavens for signs of other advanced civilisations in the universe. And we've found nothing. Absolutely nothing. So maybe we shouldn't be so focused on intelligent life, but on any sort of life whatsoever. Sure, a tiny microbe may not be as exciting as swapping stories with distant aliens, but signs of non-intelligent life may be much more common – and much easier to find – in our galaxy.

Life, including intelligent life, evolved here on Earth. Yet there shouldn't be anything particularly remarkable about our planet; it's just another random world in the galaxy. So if intelligent life happened here, it must be pretty common – widespread enough that we should be seeing signs of alien civilisations all over the place. So, where is everybody? This is the heart of the infamous Fermi paradox, and it's the main argument used to fuel the search for extraterrestrial intelligence (SETI). At first glance, it seems immediately obvious that we should not be alone in the universe, and so if we look hard enough, we should see some evidence for intelligence.

Perhaps aliens are blasting radio signals for us to listen to. Perhaps they're just generally blasting the radio, and we happen to pick it up. Perhaps they've left artefacts in the Solar System, designed to monitor us or just hang around. Perhaps they'll engage in mega-engineering projects, like enclosing their star in a swarm of solar panels. Or perhaps they'll just play around and contaminate their star with heavy metals to announce their presence. After over half a century of SETI, however, we've found nothing. No radio signals. No artefacts. No mega-engineering. To date, after over a hundred dedicated searches, we have absolutely no evidence for any intelligent life in our galaxy, or even in the universe.

BIO

PAUL M. SUTTER

Sutter is a research professor in astrophysics at the Institute for Advanced Computational Science at Stony Brook University and a guest researcher at the Flatiron Institute in New York City. He is also the author of two books: *Your Place in the Universe* and *How to Die in Space*.

"SIGNS OF NON-INTELLIGENT LIFE MAY BE MUCH MORE COMMON – AND MUCH EASIER TO FIND – IN OUR GALAXY"

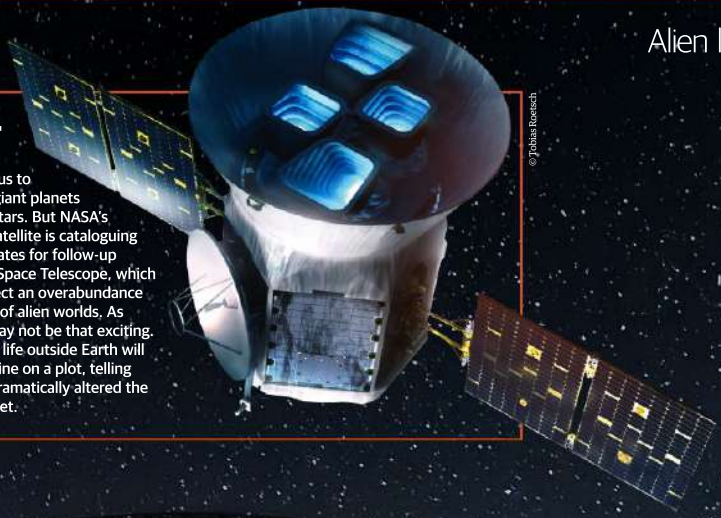
SHOULD WE LOWER OUR STANDARDS?

Perhaps we should just search for extraterrestrial life, rather than focusing on advanced alien civilisations. That means any kind of life: single-celled organisms floating in oceans, moss clinging to rocks or the first hints of complex creatures moving around their environments. Sure, these kinds of life forms may not be as loud as intelligent life, but that doesn't make them invisible. Indeed, one of the key features of any kind of life is the ability to throw a planet out of equilibrium.

© Getty

FIRST CONTACT

Our current technology limits us to studying the atmospheres of giant planets orbiting close to their parent stars. But NASA's Transiting Exoplanet Survey Satellite is cataloguing a number of promising candidates for follow-up studies with the James Webb Space Telescope, which will have the capability to detect an overabundance of oxygen in the atmospheres of alien worlds. As first-contact scenarios go, it may not be that exciting. It's likely our first evidence for life outside Earth will take the form of a wiggle in a line on a plot, telling us that living creatures have dramatically altered the equilibrium of their home planet.



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SETI ASSUMPTION

The assumption behind SETI is that intelligent life should be easier to detect than regular life, because intelligent creatures are capable of making their presence known. But something in this argument is going wrong. Either intelligent life isn't as common as we might have hoped, or it's not as detectable as we might have hoped.

ATMOSPHERIC CLUES

Our planet probably formed with a good deal of oxygen; there's plenty of it in the universe to go around. But oxygen is highly volatile and reactive, and it doesn't really last long on its own in an atmosphere – it either escapes into space or binds with other elements and turns into other things, like carbon dioxide or silicon dioxide. But around 2 billion years ago, a planet full of single-celled photosynthetic organisms ate enough carbon dioxide and burped out enough oxygen to completely revamp Earth's atmosphere, giving it substantially more oxygen than it would have in equilibrium. Life on Earth changed the very character of this planet's atmosphere. And that's detectable elsewhere.

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ANTI-SATELLITE MISSILE TEST DRAWS CONDEMNATION

Across the globe, nations and space companies alike are speaking out against Russia's anti-satellite test, which forced astronauts in space to take cover

Reported by Chelsea Gohd

© NPL

In 15 November 2021, the seven astronauts and cosmonauts living on board the International Space Station were forced to take shelter in the spacecraft they flew to the station. The orbiting lab was passing through a cloud of space debris that threatened the station and its inhabitants. Later that day, the US State Department revealed, with confirmation from the Pentagon, that the space debris – which will be trapped in orbit for years to come – was the result of a Russian anti-satellite (ASAT) test.

The test, which saw a missile destroy Kosmos 1408, a defunct Soviet satellite, has now drawn criticism from nations around the world and private spaceflight companies. These statements follow stark criticism of the test from the US government, as well as NASA administrator Bill Nelson.

"In addition to destroying the fragile space environment, this kind of sabre-rattling is a clear reminder that the space infrastructure we rely on for our economy, for science and for national security is threatened by human aggression,"

> "THE THREAT POSED BY ANTI-SATELLITE WEAPONS HAS STEADILY GROWN SINCE 2007"
>
> VIRGIN ORBIT

said Virgin Orbit CEO Dan Hart. "Virgin Orbit joins with the broader space community to universally condemn this destructive and irresponsible act," the company added.

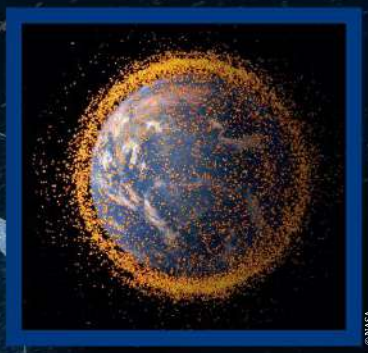
The Commercial Spaceflight Federation also spoke out about Russia's actions in space. The organisation, which represents the commercial spaceflight industry, with over 90 member companies, stated that it "strongly condemns the deliberate destruction of satellites, endangering humans in orbit and other spaceflight activities."

Japan also spoke out: the foreign ministry called the test "an irresponsible behaviour that undermines sustainable and stable use of outer space". The ministry added that Russia's test "runs counter to the Space Debris Mitigation Guidelines" put together by the Inter-Agency Space Debris Coordination Committee (IADC) and unanimously adopted by the member states of the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS). With these guidelines in place, member states are mandated to avoid intentionally destroying space objects in orbit that could create space junk that would stay in orbit long term.

Australia also spoke out, with Peter Dutton, the nation's defence minister, stating that the test was "a provocative and dangerous act that demonstrated the threats to space systems are real, serious and growing". Australia's minister for foreign affairs, Marise Payne, said: "Russia's actions are not those of a nation committed to ensuring the peaceful use of space, nor the prevention of an arms race in outer space."

South Korea's foreign ministry has also spoken out about the event. The ministry said "we are concerned about the anti-satellite weapon test that took place 15 November, and in particular numerous pieces of debris created in space as a result of the test." The ministry added that there is a need for "all nations to act responsibly in space to ensure peaceful and sustainable use of space, and work together to advance related international rules."

China has yet to make an official statement about the ASAT test, but during a 16 November news conference, China's foreign ministry spokesperson Zhao Lijian said that "we noted relevant reports and that Russia has yet to respond. I think it is too early to make any comment." China has previously found itself as the target of criticism for conducting an ASAT test in 2007. "The threat posed by anti-satellite weapons has steadily grown since 2007, when China performed a similar test and created a similar debris field that is still being tracked today," said Virgin Orbit.



Right: Earth is surrounded by human-made satellites and debris

© NASA

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DWARF PLANET PROFILE

MAKEMAKE

Makemake is partly responsible for Pluto's controversial change in planetary status

Reported by Daisy Dobrijevic

Makemake is a dwarf planet in the outer Solar System. It was the fourth body to be identified as a dwarf planet. Makemake is large and bright enough to be studied by a high-end amateur telescope. Makemake was first observed in March 2005 by a team of astronomers at the Palomar Observatory in California. Provisionally known as 2005 FY_9, the tiny planetoid was nicknamed Easterbunny by the group. The team was also responsible for the discovery of dwarf planet Eris and involved in the controversial discovery of the dwarf planet Haumea. Makemake is named for the god of fertility in Rapa Nui mythology. The Rapa Nui live on Easter Island in the southeastern Pacific Ocean. Makemake was the chief god, the creator of humanity and the god of fertility.

Makemake is the second-brightest known object in the outer Solar System, just slightly dimmer than Pluto. At 1,400 kilometres (870 miles) wide, it's about two-thirds the size of the more well-known dwarf planet. It orbits beyond the range of Pluto, but closer to the Sun than Eris, taking approximately 305 Earth years to circle the Sun. Makemake is reddish-brown in colour, leading scientists to conclude that it contains a layer of methane at its surface, possibly in pellets. Signs of frozen ethane and frozen nitrogen have also been determined.

Astronomers took advantage of the dwarf planet's passage in front of a star – called an occultation – to determine that it lacks a significant atmosphere, a surprise given its similarities to Pluto, which has a thin one. The scientists also calculated how much light the planet reflected, a rate comparable to dirty snow. The planet is dimmer than Pluto but brighter than Eris.

Like all the known dwarf planets but Ceres, Makemake travels through the Kuiper Belt, the region of ice and rock at the outer edges of the Solar System. It can travel as far out as 53 times the distance between Earth and the Sun and come as close as 38 times that same distance throughout its orbit. Makemake spins on its axis once every 22.5 hours, with a day just shorter than Earth's. Makemake's moon, designated S/2015 (136472) 1, but nicknamed MK 2, is about 160 kilometres (100 miles) in diameter. It lies about 20,900 kilometres (13,000 miles) from the surface of Makemake.

Makemake, along with Eris and Haumea, was responsible for Pluto's drop in status from planet to dwarf. Though Makemake and Haumea are just smaller than Pluto, Eris is more massive; Ceres, found in the asteroid belt, is the smallest of the bunch. In 2006, the International Astronomical Union (IAU) created a new category of bodies known as 'dwarf planets' and reclassified the definition of a planet. A planet circles the Sun but doesn't orbit anything else, is large enough to be rounded by its own gravity and has cleared its neighbourhood of orbiting bodies. Pluto failed to make the cut because it doesn't clear the debris in its orbital path.

"MAKEMAKE IS THE SECOND-BRIGHTEST KNOWN OBJECT IN THE OUTER SOLAR SYSTEM, SLIGHTLY DIMMER THAN PLUTO"

© NASA, ESA

Above: Hubble image of Makemake and its moon

Below: Makemake is located in the Kuiper Belt in the outer Solar System

COMPOSITION

Frozen methane and ethane on the surface

A thin atmosphere, most likely composed of nitrogen, may develop on Makemake when it makes its closest approach to the Sun

© Getty

NEWS FROM THE OUTER SOLAR SYSTEM

DWARF PLANET LACKS AN ATMOSPHERE

In 2011, distant starlight gave astronomers the best look yet at Makemake. Although this icy world currently lacks an atmosphere, there's still a chance it could form one when it approaches the point in its orbit closest to the Sun. Makemake passed directly in front of the distant star NOMAD 1181-0235723. This eclipse, or occultation, helped backlight the icy world, helping researchers pin down Makemake's size, shape and surface properties better than ever.

Such occultations are extremely difficult to predict and observe. For comparison, these worlds are so distant they appear about the same size "as that of a coin seen at a distance of 50 kilometres (30 miles) or smaller," said planetary scientist José Luis Ortiz Moreno. "But thanks to our hard work and to an important international collaboration, we were able to beat all the difficulties." At most, Makemake's atmosphere is 80 million to 250 million times thinner than Earth's at sea level, the researchers calculated. Still, there might be patches of atmosphere overlying warmer regions on its surface, such as dark patches that absorb more sunlight.

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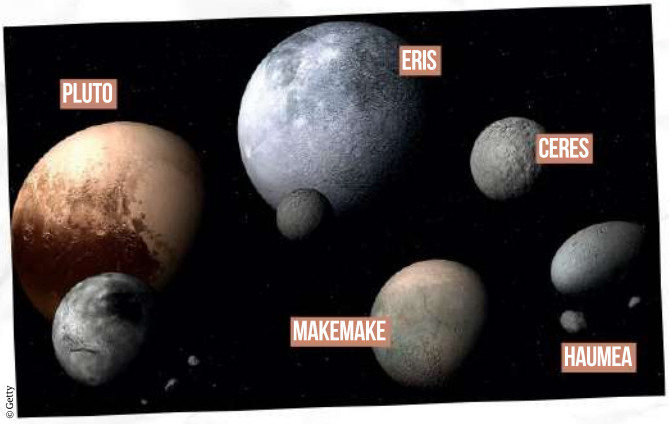

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MEET THE SOLAR SYSTEM'S DWARF PLANETS

Pluto's demotion was spurred by the discovery of multiple large bodies orbiting even farther from the Sun than Pluto – particularly an object called Eris, which appeared to be bigger than Pluto. As a result, the IAU came up with a new definition of a planet: a body that circles the Sun without being another object's satellite, one large enough to be rounded by its own gravity and that has 'cleared its neighbourhood' of most other orbiting bodies.

Since Pluto shares orbital space with lots of other objects out in the Kuiper Belt – the ring of icy bodies beyond Neptune – it didn't make the cut. So Pluto was newly classified as a dwarf planet, which tend to be smaller than 'true' planets and fall short on the 'clearing your neighbourhood' criterion. Although hundreds – or perhaps even thousands – more Solar System bodies may eventually join the list, the IAU officially recognises just five dwarf planets at the moment: Pluto, Eris, Haumea, Makemake and Ceres.

HAUMEA'S ELUSIVE RING

The rugby ball-shaped Haumea, which is surrounded by an almost perfectly circular ring of particles, is the most distant ringed object in the Solar System. Haumea's ring is too faint to be seen from Earth, so astronomers have turned to clues to find out more about these particles. Researchers with the São Paulo Research Foundation in Brazil have detailed the ring's size, shape and other characteristics by simulating the Haumea system on a computer. By simulating the ring's particles in different configurations around the dwarf planet and calculating which scenario would render the ring most stable, scientists were able to infer the likely qualities of the ring without ever looking at it directly.

Astronomers first spotted Haumea far beyond the orbit of Pluto in 2004; it was originally classified as a Kuiper Belt Object (KBO). The dwarf planet's two moons, Hi'iaka and Namaka, were first seen in 2005 by astronomers using the W. M. Keck Observatory in Hawaii. As astronomers began to find more objects like Haumea floating in the outer region of the Solar System, the dwarf planet later became one of a handful of far-out bodies in this classification.

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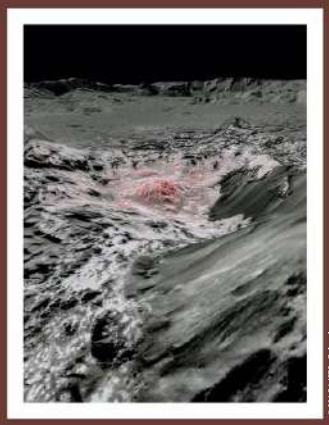
GIANT CRATER ON CERES WITH BRIGHT SPOTS MAY BE THE MOST FASCINATING PLACE IN THE SOLAR SYSTEM



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Left: The spots reveal information about Ceres' geological past

Below: A rendering of sunrise on the reddish-brown dwarf planet

For a few months in 2018, as NASA's Dawn spacecraft used up its last drops of fuel, it gave scientists an incredibly detailed look at one of the strangest places in the Solar System: Occator crater. That's the name of a massive impact site on the dwarf planet Ceres, tucked away in the asteroid belt. In the mission's last months, Dawn flew just 35 kilometres (22 miles) above the dwarf planet's surface and focused its energies on Occator crater. The data collected from Dawn suggests that cryovolcanism may have begun just 9 million years ago on Ceres, continuing for several million years. A series of bright deposits formed over that time from brine seeping out from Ceres' mantle through the upper layer of rock, with activity recorded as recently as a million years ago.

Another finding is a specific form of salt found so far only on Earth – and now on Ceres – that is particularly short-lived, on the scale of centuries. The combination suggests that the brines that deposited them on the surface must have done so very recently. These salts could also solve the puzzle of what's keeping Ceres relatively warm without gravitational tugging, and could be responsible for maintaining pockets of liquid within the dwarf planet.

MAKEMAKE TIMELINE

- **Date:** 4.5 billion years ago
  Activity: Makemake formed alongside other icy worlds in the Kuiper Belt early in the history of our Solar System.
- **Date:** March 2005
  Activity: Makemake is observed for the first time by scientists Mike Brown, Chad Trujillo and David Rabinowitz at the Palomar Observatory in California.
- **Date:** 19 July 2008
  Activity: Makemake is officially named by the International Astronomical Association.
- **Date:** April 2011
  Activity: Astronomers determined Makemake had no atmosphere after observing its occultation of a faint star.
- **Date:** April 2016
  Activity: NASA announces the discovery of Makemake's moon MK 2.

MAKEMAKE BY NUMBERS

6 HOURS 20 MINUTES
How long it takes sunlight to reach Makemake

1,300
How many times fainter MK 2 is compared to Makemake

715 KILOMETRES
Makemake's radius

12
Estimated length of time, in days, MK 2 takes to complete an orbit of Makemake

45.8AU
Average distance Makemake is from the Sun in astronomical units, with one AU being the Earth-Sun distance

5
The current number of recognised dwarf planets in our Solar System

"LIKE ALL THE KNOWN DWARF PLANETS BUT CERES, MAKEMAKE TRAVELS THROUGH THE KUIPER BELT"

© Getty

Focus on

WHAT HAPPENS TO EARTH'S DISAPPEARING CRUST?

Scientists may have finally figured out the mystery of subduction zones

Reported by Yasemin Saplakoglu

Like a giant broken-up cookie whose pieces float atop a sea of scalding milk, Earth's outer shell is made of rocky rafts that constantly bump into and dive beneath each other in a process called plate tectonics. So what happens to those hunks of disappearing crust as they dive into Earth's interior? It turns out that they get weak and bendy, like a slinky toy, but new modelling shows that they don't disintegrate completely. The models also suggest that plate tectonics, at least in their modern form, likely only got going in the past billion years.

Plate tectonics drive earthquakes and volcanoes, create mountain ranges and islands and are the reason Earth's continents - once a supercontinent - are now oceans apart. But there's still much unknown about how plate tectonics work, such as what happens when a plate slides beneath another and disappears into the mantle, the middle layer of the planet, which is composed of sizzling solid rock.

To figure this out, researchers used 2D computer models of subduction zones and programmed them using known physics of how materials behave, such as how rocks deform under certain forces. Then they observed the model to see what happened at the subduction zone and compared their findings to real-life observations. Their models suggested that as one plate dove beneath another, the descending piece, known as a slab, abruptly bent downwards and cracked; the bending also caused the grains on the underside of the plate to become finer and weaker. The pressures left the plate mostly intact, but with many weak points.

That means that the plates don't break apart, and thus keep pulling on the parts behind them "for a very long time," said Taras Gerya, a professor of geophysics at the Swiss Federal Institute of Technology. Indeed, the plate can keep sliding under the other plate for hundreds of millions of years.

"MODERN PLATE TECTONICS MAY NOT HAVE BEGUN UNTIL SOMETIME IN THE PAST BILLION YEARS"

The team of researchers also modelled what would have happened if Earth's interior were 150 degrees Celsius (270 degrees Fahrenheit) hotter, similar to temperatures it would have reached about a billion years ago.

They found that in these simulations, the slab broke up only a few miles into the mantle. This was because it was unable to sustain its own weight in a mantle that was less viscous due to the hot conditions. Unlike modern subduction, which can continue for hundreds of millions of years, subduction back then would have ended very quickly, within a few million years, Gerya said.

This finding suggests that modern plate tectonics may not have begun until sometime in the past billion years, he added. While a primitive form of plate tectonics may have existed between 3.5 billion and 2 billion years ago, during the Archean or Proterozoic eras, it was probably very different from what the planet experiences today. And around 1.8 billion to 1 billion years ago, there was a quiet period in which the plates were much less active. But this is just speculation, he said, and there is currently a lot of controversy surrounding when plate tectonics started.

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ALL ABOUT THE ORION NEBULA

EVERYTHING YOU NEED TO KNOW ABOUT THIS CRADLE OF BABY STARS THAT'S VISIBLE FROM EARTH

Written by Daisy Dobrijevic

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The Orion Nebula (Messier 42) is the nearest star-forming region to Earth, located around 1,345 light years away, and is about 2 million years old. The billowing clouds of gas and dust are located in the constellation of Orion, just below Orion's Belt. The majestic nebula can be seen with the naked eye, as it has an apparent magnitude of +4.0. It's no surprise that the Orion Nebula has captivated civilisations around the world for centuries – for example, the Maya of Mesoamerica interpreted the nebula as the cosmic fire of creation.

The Orion Nebula is part of a larger stellar network called the Orion Molecular Cloud Complex, one of the most active star-forming regions visible in the sky. The Orion Complex consists of several molecular clouds, including the Lambda Orionis Molecular Ring, the Orion A Cloud, which includes the Orion Nebula, and the Orion B Cloud, which includes the Flame Nebula. The bustling stellar nursery is brimming with towering pillars of gas and dust, home to fledgling stars. The entire scene is sculpted by young stars ejecting charged particles as stellar wind and emitting powerful ultraviolet light.

In the central region of the Orion Nebula are four bright stars in an open star cluster, known as the Trapezium due to their trapezoidal arrangement. These hot, young stars emit ultraviolet light that carves through the core of the nebula, leaving large cavities void of the thick clouds of gas and dust. The large chasm carved by the Trapezium conveniently faces Earth, allowing observers to peer into the nebula's 'heart' and view the rich tapestry of star formation within.

In 2006 the Hubble Space Telescope captured the sharpest view of the Orion Nebula in a stunning image, revealing more than 3,000 stars, some for the very first time. But not all of the stars in the Orion Nebula are 'successful'; Hubble has

THE ORION CONSTELLATION

Orion is clearly visible in the night sky of both hemispheres from November to February. Finding Orion's Belt is the easiest way to locate the constellation of Orion.

Orion's Belt is formed by three bright stars: Alnilam, Mintaka and Alnitak. Orion can be located in the southwestern sky if you are in the Northern Hemisphere or the northwestern sky if you are in the Southern Hemisphere. It's best seen between latitudes of 85 and -75 degrees. Its right ascension is five hours, and its declination is minus five degrees.

Betelgeuse, the second-brightest star in Orion, establishes the right shoulder of the Hunter, while Bellatrix serves as Orion's left shoulder. Other stars in the constellation include Hatsya, which establishes the tip of Orion's Sword, which hangs off his belt, and Meissa, which forms Orion's head. Saiph serves as Orion's right knee. Rigel, Orion's brightest star, forms the Hunter's left knee.

With just one exception, all of the main stars in Orion are bright, young blue giants or supergiants, ranging in distance from Bellatrix, at 243 light years, to Alnilam, which is 1,360 light years distant. The exception is the star Betelgeuse, which is a red giant and one of the largest known stars. Observers with a keen eye should be able to see the difference in colour between Betelgeuse and all the other stars in Orion. The Orion Nebula is located around 1,345 light years away from Earth.

Below: The bright lights of the Trapezium can be seen in the centre of the nebula

© NASA/ESA & Hubble

ORION NEBULA BY NUMBERS

+4.0
Apparent magnitude of the Orion Nebula

2
MILLION YEARS
Approximate age of the Orion Nebula

1,345
Light years between the Orion Nebula and Earth

05H 35M 17.3S
RIGHT ASCENSION
-05° 23' 28"
DECLINATION
Coordinates for locating the Orion Nebula

1610
The year the first observation of the Orion Nebula was made with a telescope, by Nicolas-Claude Fabri de Peiresc

30-40
Estimated diameter of the Orion Nebula in light years

observed a myriad of brown dwarfs in the Orion Nebula. Brown dwarfs are sometimes referred to as 'failed' stars as they're too small to sustain nuclear fusion in their cores. Brown dwarfs are not quite massive enough to be stars, but are more massive than planets, usually falling between 13 and 80 times the mass of Jupiter.

As the constellation of Orion is easy to locate and visible throughout the world, both in the Northern and Southern Hemisphere, the Orion Nebula – nestled within the constellation – is a popular stargazing target for amateur astronomers. To find the Orion Nebula, you first need to locate the constellation of Orion, then find Orion's Belt. Under Orion's Belt are three dimmer stars that make up Orion's Sword, and in the middle of the sword is the Orion Nebula.

To the naked eye the nebula appears as a fuzzy, grey smudge under Orion's Belt. But with the help of a pair of binoculars or a telescope, you should be able to pick out more of Orion's distinguishing features, including the bright central part of the nebula called the 'Huygenian region', named after 17th-century astronomer Christiaan Huygens.

With the right equipment and set-up, astrophotographers can capture stunning images of the Orion Nebula which can rival even the Hubble Space Telescope's, making the Orion Nebula a popular target for both stargazers and astrophotographers alike. In one of the most impressive images of the Orion Nebula, captured by the Hubble Space Telescope, the different colours captured are attributed to different chemical elements: the orange colour can be attributed to hydrogen, the green to oxygen and the red represents both sulphur and infrared light observations.

Unlike Hubble, our eyes cannot distinguish the vibrant hues of the Orion Nebula. This is because our eyes contain two different kinds of photoreceptors: cones and rods. Cone cells are active at higher light levels and can perceive colour, whereas at low light levels our rod cells sense light but cannot perceive colour or fine details. Due to this, the Orion Nebula appears as a grey smudge to most when viewed with the naked eye, with binoculars or with a telescope. However, if viewing conditions are right it's possible to see

Below: A close-up view in visible light shows many brown dwarf stars encompassed within the Orion Nebula

Right: One of the most detailed astronomical images ever captured

© NASA/ESA & Hubble

the blue-green hues emitted by oxygen ions in the Orion Nebula. Some stargazers are fortunate enough to detect the green hues because the human eye is more sensitive to yellow-green light as opposed to red; if any colour is to be detected from the Orion Nebula, it's likely to be at the green end of the spectrum.

Though we may not be able to see all the impressive colours of the Orion Nebula directly, by using the right filters and image-processing techniques, astrophotographers can produce visually stunning images of the Orion Nebula, awash with vibrant colour.

Our fascination with the Orion Nebula is not a recent phenomenon. Over centuries, the spectacle has caught the attention of cultures around the world. One civilisation in particular was the Maya, where Orion was an intrinsic part of the culture. The astronomical interpretations and mythological beliefs of inhabitants at sites such as El Mirador are reflected in the architecture found at the sites, particularly the astronomically inspired 'triadic pattern'. One example of the importance of this triadic pattern within Maya life is the three hearthstones, or Ox Te' Tuun, found in every Maya kitchen. It's been suggested that the three stones represented three stars in the constellation of Orion – Rigel, Alnitak and Saiph. The fire and smoke at the centre of the hearth represented the Orion Nebula, which was interpreted by the Maya as the cosmic fire of creation.

The first observation of the Orion Nebula with a telescope was in 1610 by French scholar Nicolas-Claude Fabri de Peiresc. It was then independently observed in 1618 by Swiss astronomer Johann Baptist Cysat. As one of the brightest nebulae in the sky, it comes as no surprise that the Orion Nebula was the first to be photographed. In 1880 Henry Draper captured the first image of the Orion Nebula, and astrophotographers have been captivated by it ever since.

Daisy Dobrijevic
Staff Writer
Daisy is **All About Space**'s Staff Writer. She previously worked for *BBC Focus* as a researcher and *BBC Sky at Night* magazine as an editorial assistant.

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NEARBY OBSERVING TARGETS

Orion is home to many interesting stargazing targets alongside the Orion Nebula

© ESA/Hubble & NASA

HORSEHEAD NEBULA (BARNARD 33)

Magnitude: +6.8

Approximate distance from Earth: 1,500 light years

Right ascension: 05h 40m 59s

Declination: -02° 27' 30"

The Horsehead Nebula is a tricky target to track down, but it's not impossible to find with a good telescope. The nebula can be found just south of the easternmost star in Orion's Belt. The shape of the nebula is forged by radiation from the surrounding stars. The nebula is only visible because the dust is silhouetted against a brighter nebula.

© ESA/Hubble & NASA

DE MAIRAN'S NEBULA (MESSIER 43)

Magnitude: +9.0

Approximate distance from Earth: 1,300 light years

Right ascension: 5h 35m 31.8s

Declination: -5° 17' 57"

Only separated from the Orion Nebula by a dark lane of dust, this was revealed to be a distinct nebula by French astronomer Jean-Jacques d'Ortous de Mairan in 1731. Astronomers refer to De Mairan's Nebula as a miniature Orion Nebula because of its small size. The nebula is shaped by just one star, whereas the Orion Nebula is shaped by four.

© NASA/JPL-Caltech

THE FLAME NEBULA (NGC 2024)

Magnitude: +2.0

Approximate distance from Earth: 1,354 light years

Right ascension: 05h 41m 54s

Declination: -01° 51' 00"

Close to the Horsehead Nebula you can find the impressive Flame Nebula, an emission nebula home to a few hundred young stars. The stars within the nebula vary quite considerably in age – those close to the centre are approximately 200,000 years old, while stars on the outskirts are estimated to be around 1.5 million years old.

POTENTIAL EARLY UNIVERSE FOSSIL UNCOVERED

The weird stellar remnant may be from one of the first stars in the cosmos

Reported by Harry Baker

Astronomers have detected an extremely unusual star that they believe is a stellar fossil, or remnant, of one of the universe's very first stars. The star, AS0039, is located in the Sculptor Dwarf Galaxy around 290,000 light years from the Solar System. This stellar remnant has the lowest concentration of metal, particularly iron, of any star measured outside the Milky Way. The researchers think it's evidence that the remnant is a direct descendent of one of the universe's earliest stars, which contained very little metal.

Researchers found that the primordial parent star of AS0039 would have been around 20 solar masses and likely died in a hypernova – a stellar explosion 10 to 100 times more powerful than a regular supernova. The discovery may reveal new information about the universe's first stars, which have never been directly or indirectly observed until now. "AS0039 has such an unusual chemical composition that it enables us to probe the nature of the first stars, in particular their stellar mass," said Mike Irwin, an astronomer at the University of Cambridge.

Though all stars are balls of hot gas called plasma, fuelled by the fusion of elements in their cores, they are also extremely diverse; they can range widely in size and colour. But all stars can be classified into three distinct groups – Population I, Population II and Population III – based on their chemical composition, or metallicity.

Population I stars, like the Sun and most other stars in the observable universe, have high metal content, especially iron, and are rich in relatively heavy elements like calcium and magnesium. Population II stars, such as AS0039, are much rarer; these metal-poor stars contain only trace amounts of heavy elements. Population III stars, which have never been seen, are almost totally metal-free and have zero heavy elements. Although Population III stars have never been detected, astronomers know that the very first stars born in the universe would have been Population III stars, Irwin said.

During nuclear fusion, hydrogen atoms are fused together into helium, which releases an enormous amount of energy. Most stars – those up to around 1.4 solar masses – slowly use up their hydrogen fuel until there is none left, swell up to red giants and eventually collapse into white dwarfs.

However, larger stars quickly use up their hydrogen, instead beginning to fuse helium into carbon, and eventually carbon into iron, which is the heaviest element a star can create. Eventually, these large stars become too dense, collapse in on themselves and explode in a supernova, which not only disperses the star's elements into the surrounding space, but also releases enough energy to create elements heavier than iron, such as gold.

New stars are often birthed in the clouds of gas left behind from previous stars, so when they form, they take in some of the metal and heavy elements from the exploded stars that came before them. As a result, all the stars observed today are Population I or II stars, because they formed from the leftovers of the stars that came before them. The first stars in the universe, Population III stars, formed from pure hydrogen, which was the first element created after the Big Bang. "Population III stars are defined to be the first generation of stars to have formed in the universe, and hence were formed from zero metallicity," said Irwin. These primary stars also lacked heavy elements because no supernovae had created them.

When researchers found AS0039, they were amazed at how metal-poor it was, even compared with other Population II stars. AS0039 has the lowest metal concentration of any star studied outside our own galaxy, as well as the lowest carbon concentration of any star ever studied in the universe. It also has unusual ratios of heavier elements, particularly magnesium and calcium, in very low quantities. These findings suggest that AS0039 may be a second-generation star that formed out of the remains of a Population III star. Computer simulations suggested that the Population III star that birthed AS0039 likely died in a powerful hypernova. "We believe that Population III stars were generally more massive than stars that we see today, so it wouldn't be surprising if a Population III star ended up as a hypernova," Irwin said.

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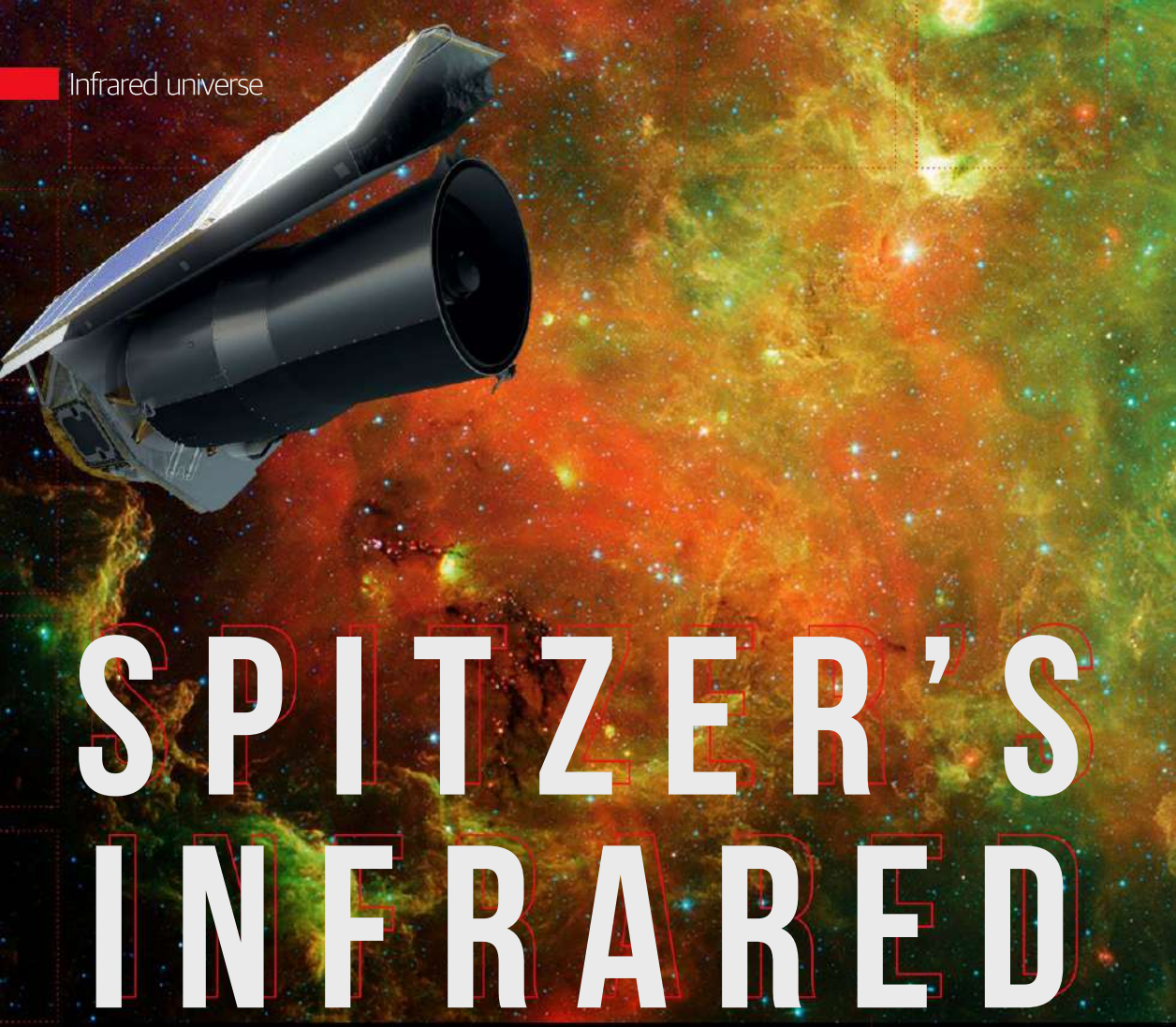
"IT ENABLES US TO PROBE THE NATURE OF THE FIRST STARS"

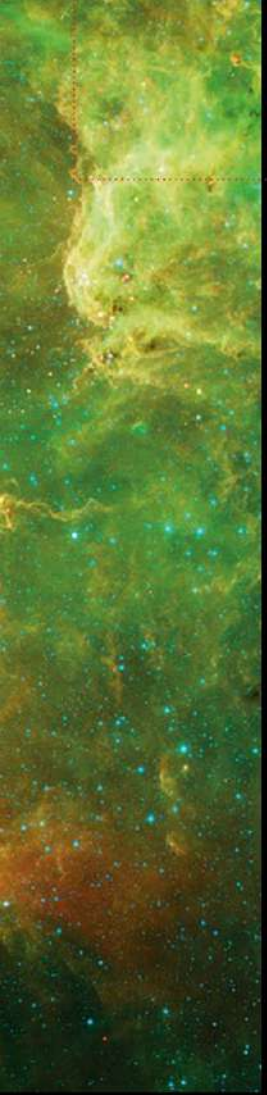
MIKE IRWIN



SPITZER'S INFRARED UNIVERSE

IN JANUARY 2020, NASA'S SPITZER SPACE TELESCOPE CAME TO THE END OF ITS MISSION AFTER 16 YEARS OF INCREDIBLE IMAGES – HERE'S JUST A FEW OF OUR FAVOURITES

Written by Hanneke Weitering



CARINA NEBULA

Massive stars can wreak havoc on their surroundings, as can be seen in this view of the Carina Nebula. The bright star at the centre of the nebula is Eta Carinae, one of the most massive stars in the galaxy. Its blinding glare is sculpting and destroying the surrounding nebula.

NORTH AMERICA NEBULA

Spitzer captured this infrared view in 2011. Since infrared light can penetrate dust, the shape of the nebula - which usually resembles the continent of North America - changes completely. The dusty, dark clouds in visible-light images vanish in Spitzer's view. In addition, Spitzer's infrared detectors display the glow of dusty cocoons enveloping baby stars.

THE SWAN NEBULA

Spitzer captured this infrared view of the choppy star-making cloud Messier 17, also known as the Omega Nebula or the Swan Nebula, in 2008. The region lies around 5,500 light years away in Sagittarius.

DUMBBELL NEBULA

The Dumbbell Nebula, also known as Messier 27, pumps out infrared light in this image. The nebula was named after its resemblance to a dumbbell as seen in visible light. It was discovered in 1764 by Charles Messier, who included it in his famous catalogue of nebulous objects.

PENGUIN AND EGG GALAXIES

The galaxies NGC 2336 and NGC 2937 look like a penguin and its egg respectively in this photo, which incorporates data from NASA's Hubble and Spitzer space telescopes.

HELIX NEBULA

This infrared image from Spitzer in 2007 shows the Helix Nebula, a cosmic starlet often photographed by amateur astronomers for its vivid colours and eerie resemblance to a giant eye in the sky.

All images © NASA/JPL-Caltech

GREEN RING NEBULA

A glowing ring spotted in space seems more like superhero fiction than science fact. But that's what Spitzer found in the murky clouds encircled by the tail of Scorpius. This photo of the bright emerald-green nebula, released in 2011, is reminiscent of the glowing ring wielded by the Green Lantern.

A DUSTY MAGELLANIC CLOUD

This image shows the Large Magellanic Cloud in infrared light as seen by Spitzer and the European Space Agency's Herschel Space Observatory. In this combined image, the dwarf galaxy looks like a fiery, circular explosion. Those ribbons are actually giant ripples of dust.

"THIS PHOTO OF THE BRIGHT EMERALD-GREEN NEBULA IS REMINISCENT OF THE GLOWING RING WIELDED BY THE GREEN LANTERN"

SPIRAL GALAXY SPIDER WEB

Looking like a spider's web swirled into a spiral, the galaxy IC 342 presents its delicate pattern of dust in this image, captured by Spitzer in 2011. Seen in infrared light, the faint starlight gives way to the glowing patterns of dust found throughout the galaxy's disc.

GALAXY BLASTED WITH A DEADLY JET

Spitzer captured a powerful jet from a supermassive black hole blasting a nearby galaxy in the system known as 3C 321. This galactic violence could have a profound effect on any planets in the path of the jet and trigger a burst of star formation.

BLACK HOLE IN A COSMIC STORM

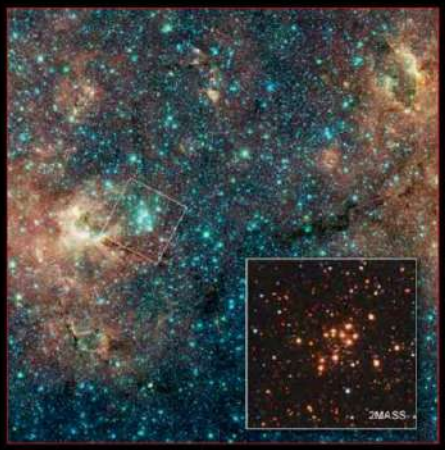
The 'eye' at the centre of the barred spiral galaxy NGC 1097 is caused by a monstrous black hole. It can't be seen, but is surrounded by a ring of stars and rampant star birth. In this colour-coded infrared view from Spitzer, the area around the invisible black hole is blue and the ring of stars is white.

SUPERNOVA REMNANT HBH 3

This supernova remnant is one of the largest in the Milky Way, measuring about 150 light years across. It's also one of the oldest; the star that exploded to create this cosmic spectacle did so 80,000 to 1 million years ago. Spitzer captured this image in May 2010, and NASA released it on 2 August 2018.

STELLAR FIREWORKS

Astronomers traced the source of mysterious high-energy X-rays and gamma rays in space to a little known star cluster in the Milky Way. This infrared image shows a region in the Scutum constellation where a massive star cluster containing red supergiants (inset) was discovered.



MOUNTAINS OF CREATION

Giant clouds of gas and dust harbouring embryonic stars rise majestically into space in this snap by Spitzer. The image, dubbed the Mountains of Creation by astronomers, reveals hotbeds of star formation similar to the iconic Pillars of Creation within the Eagle Nebula, photographed in 1995 by Hubble.

CYGNUS X STAR BIRTH

A bubbling cauldron of star birth, Cygnus X is highlighted in this 2012 image from the Spitzer Space Telescope. Infrared light – which we can't see with our eyes – has been colour-coded so that the shortest wavelengths are shown in blue and the longest in red. The middle wavelength range is green.

CASSIOPEIA A

Stars don't always rip apart in violent explosions. Some blow up in an orderly fashion. Cassiopeia A blew up in such a tidy manner that it retained much of its original layering. In this false-colour image, the blue glow is material heated by a forward shock wave, while green, yellow and red represent material heated by a reverse wave.

'HEART' OF THE MILKY WAY

In this image, observations using infrared and X-ray light see through the obscuring dust and reveal the intense activity near the galactic core of the Milky Way. The image combines data from Hubble, Spitzer and the Chandra X-ray Observatory.

THE SOMBRERO GALAXY

The infrared vision of Spitzer has revealed that Messier 104, or the Sombrero Galaxy – named after its appearance in visible light to a wide-brimmed hat – is in fact two galaxies in one. It's a large elliptical galaxy (red) with a thin disc galaxy (blue-green) embedded within.

All images © NASA/JPL-Caltech

RECORD-BREAKING VIEW OF THE MILKY WAY

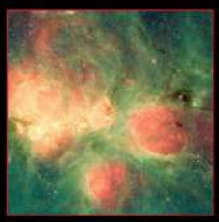
This is just a section of the largest image of the Milky Way ever created. It was stitched together from 800,000 individual infrared images taken by NASA's Spitzer Space Telescope.

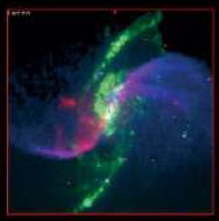
CEPHEUS STARS

Because of its infrared sensitivity, Spitzer can get a stunning look at nebulae - clouds of dust and gas peppered across the universe. The puffy green structures are nebulae, with stars scattered within them, including Cepheus C on the left and one called Cepheus B in the upper-right corner.

A GALACTIC MYSTERY

Scientists using Spitzer discovered the source of a galaxy's two ghostly extra spiral arms, which only show up in some telescope images, cracking a mystery. Messier 106, a stately spiral galaxy 23.5 million light years away in Canes Venatici, appears in visible-light images to have just two prominent arms.





THOUSANDS OF GALAXIES

A false-colour mosaic of the Coma Cluster released in 2007 revealed thousands of new faint objects, many of which belong to the cluster. The mosaic combines visible-light data from the Sloan Digital Sky Survey (blue) with long and short-wavelength infrared views (red and green respectively) from Spitzer.

THE CAT'S PAW NEBULA

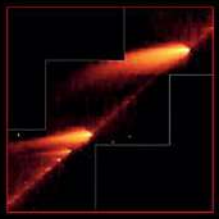
Spitzer captured this view of the Cat's Paw Nebula in 2018. The nebula, officially NGC 6334, gets its nickname from the bubbles of hot gas it contains, which resemble feline paw pads.

SPITZER SPOTS BABY STARS

By using Spitzer to peer through thick clouds of cosmic gas and dust, astronomers discovered a population of baby stars near the centre of the Milky Way. The yellow spots show the young stars that were detected in the chaotic environment at the Milky Way's centre.

COMET BREAKUP

Comet 73P/Schwassmann-Wachmann began fracturing in 1995. The breakup accelerated in 2016 as the comet approached the Sun, as it does every 5.3 years. Spitzer returned an infrared image of the scene, revealing three dozen chunks in addition to a broad stripe in the sky created by smaller pebbles and dust.



SCULPTOR GALAXY

The spectacular swirling arms and central bar of the Sculptor Galaxy are revealed in this image from Spitzer, released in 2013. Also known as NGC 253, the Sculptor Galaxy is part of a cluster of galaxies visible to observers in the Southern Hemisphere.

STELLAR CORPSE

This image from Spitzer and Chandra shows the dusty remains of a collapsed star. The composite of G54.1+0.3 shows X-rays from Chandra in blue and data from Spitzer in green and red-yellow. Scientists think that a pulsar (the white source in the centre) is sending out a wind that's heating up remnant supernova dust.

"SCIENTISTS THINK THAT A PULSAR IS SENDING OUT A WIND THAT'S HEATING UP REMNANT SUPERNOVA DUST"

ORION UNVEILED

This infrared image shows the Orion Nebula, the closest massive star-making factory to Earth.

SNOWFLAKE AND CONE

Strange shapes and textures can be found in the neighbourhood of the Cone Nebula. These patterns result from the tumultuous unrest that accompanies the formation of NGC 2264, the Snowflake Cluster. To better understand this process, a detailed image of this region was taken in two colours of infrared light.

ANDROMEDA GALAXY

This infrared composite shot from NASA's Spitzer Space Telescope highlights the contrast between the Andromeda Galaxy's choppy waves of dust (red) and smooth sea of older stars (blue).

All images © NASA/JPL-Caltech

THERE'S A BARRIER AROUND THE MILKY WAY'S CENTRE

Astronomers discover an enormous, bizarre feature separating the centre of the Milky Way from the cosmic ray sea

Reported by Brandon Specktor

The centre of the Milky Way may be even more bizarre than astronomers thought. A team of researchers from the Chinese Academy of Sciences in Nanjing investigated a map of radioactive gamma rays – the highest energy form of light in the universe, which can arise when extremely high-speed particles called cosmic rays crash into ordinary matter – blasting in and around the centre of our galaxy.

The map revealed that something near the centre of the galaxy appears to be accelerating particles to mind-blowing speeds – very near the speed of light – and creating an abundance of cosmic rays and gamma rays just outside the galactic centre.

However, even as the galactic centre blows a constant storm of high-energy radiation into space, something near the Milky Way's core prevents a large portion of cosmic rays from other parts of the universe from entering.

The researchers described the effect as an invisible 'barrier' that is wrapped around the galactic centre and is keeping the density of cosmic rays there significantly lower than the baseline level seen throughout the rest of our galaxy. In other words, cosmic rays can get out of the galactic centre, but have a much harder time getting in.

The centre of our home galaxy is located about 26,000 light years from Earth in the constellation of Sagittarius. It's a dense and dusty place, holding more than 1 million times as many stars per light year as the entire Solar System, all wrapped around a supermassive black hole with about 4 million times the mass of the Sun.

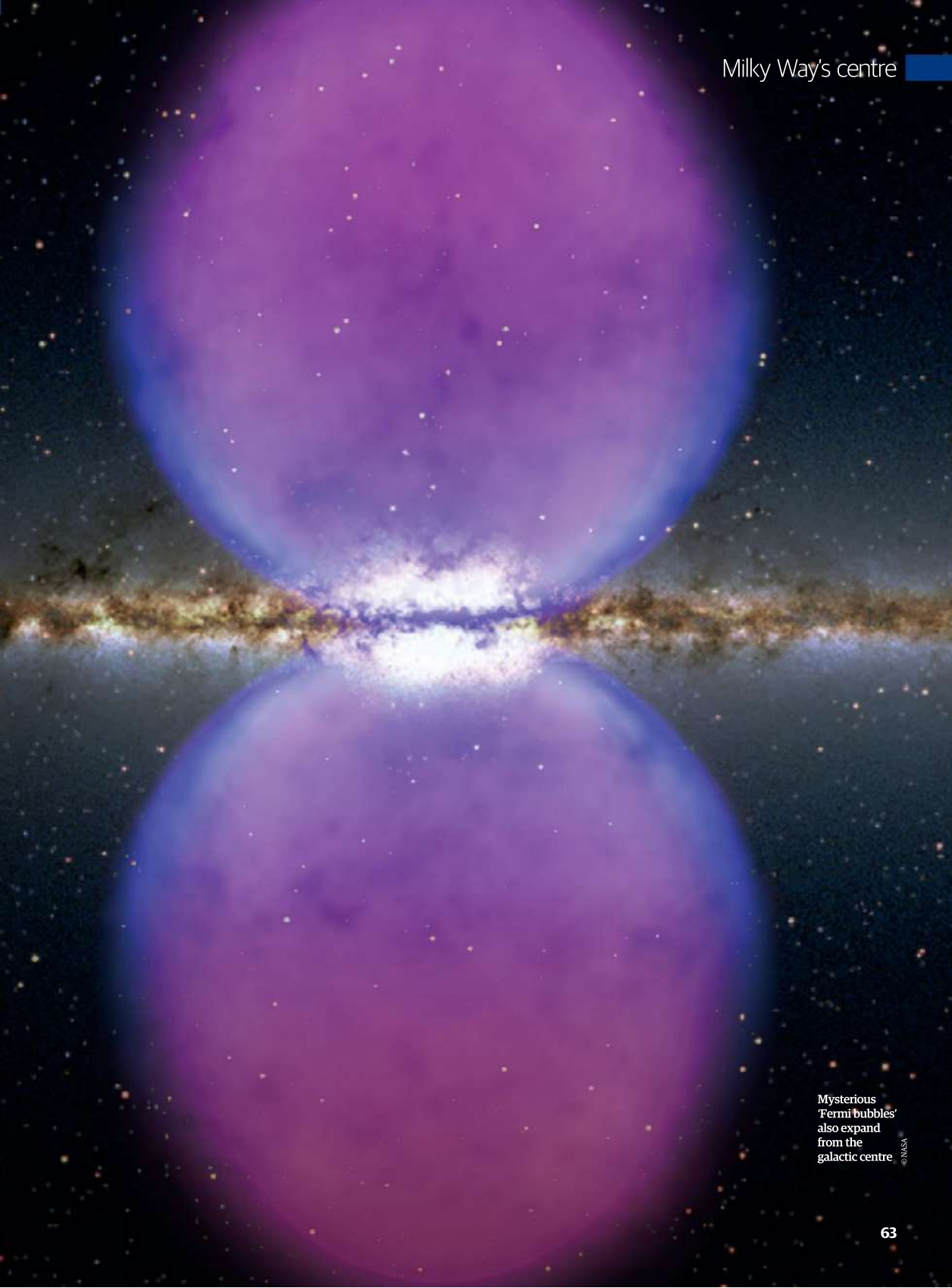
Scientists have long suspected this black hole, named Sagittarius A* (Sgr A*), or perhaps some other object at the galactic centre, is accelerating protons and electrons to near light speed, creating cosmic rays that beam throughout our galaxy and onward into intergalactic space. These rays propagate through the magnetic fields of our galaxy, creating an ocean of high-energy particles that's roughly uniform in density throughout the entire Milky Way. This steady soup of particles is called the cosmic ray sea.

The researchers compared the density of cosmic rays in this sea to the density of cosmic rays within the galactic centre. Cosmic rays cannot be seen directly, but scientists can find them in gamma-ray maps of space, which effectively show where cosmic rays have collided with other types of matter.

> "COSMIC RAYS CAN GET OUT OF THE GALACTIC CENTRE, BUT HAVE A MUCH HARDER TIME GETTING IN"

Using data from the Fermi Large Area Telescope, the team confirmed that something in the galactic centre is indeed acting as a giant particle accelerator, shooting cosmic rays out into the galaxy. Possible culprits include Sgr A* – as black holes could theoretically shoot certain particles into space even as they gobble up everything else around them – the remnants of ancient supernovae or even strong stellar winds from the many stars in the galactic centre.

But the map also revealed the mysterious 'barrier', a clear point where the density of cosmic rays drops off significantly at the edge of the galactic centre. The source of this phenomenon is harder to pinpoint, but it may involve the jumble of magnetic fields near our galaxy's dense core. For example, dense clouds of dust and gas near the galactic centre could collapse onto themselves, compressing the magnetic fields there and creating a cosmic-ray-proof barrier. Or perhaps stellar winds from the myriad of stars at the galactic centre are pushing back against the cosmic ray sea, much as the solar wind does.



Mysterious 'Fermi bubbles' also expand from the galactic centre

© NASA

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THERE'S AN ASTEROID TRACKING OUR PLANET'S ORBIT AROUND THE SUN, AND ASTRONOMERS HAVE BEEN SURPRISED BY ITS COMPOSITION

Reported by David Crookes

We all know that Earth only has one moon, and if you want proof of that, you just need to peer at the night sky. Can you see another? Astronomers are sticking to their guns by saying the Moon is Earth's only natural satellite. Case closed... or so you'd think. In 2016, however, astronomers using the asteroid-hunting Pan-STARRS telescope in Hawaii discovered a rock orbiting the Sun while also repeatedly looping around Earth. Celestial objects such as these are called quasi-satellites, and while four others have been identified since 2004, this one was the closest and most stable ever seen.

What makes it particularly interesting is its potential origin, although a recent breakthrough has gone a long way towards clearing up the five-year mystery over what this object could be. The smart money is now on it actually being a fragment of our Moon. In that sense you could say it's Earth's second moon - as some have indeed dubbed it - though it's not quite on that level, if truth be told. Still, it's no less intriguing, and astronomers are keen to discover more.

KAMO'OALEWA BY NUMBERS

9 MILLION
The closest Kamo'oalewa gets to Earth, in miles

25 MILLION
The farthest Kamo'oalewa gets from Earth, in miles

365.9
Orbital period, in days

2016
Year it was discovered

45 TO 58 METRES
The estimated size of Kamo'oalewa

30
Kamo'oalewa's rotational period, in minutes

NINE
Number of asteroids found to have lunar origins

4 MILLION
times fainter than the faintest star visible with the naked eye

500 TO 100,000
Years ago it may have broken off the Moon

Above: Rock samples collected from the Moon during the Apollo 14 mission compared almost perfectly to the data gathered about Kamo'oalewa

One of the people leading studies into the object, which is being called Kamo'oalewa – a Hawaiian name that roughly means 'oscillating celestial fragment' – is University of Arizona planetary sciences graduate student Ben Sharkey. For the past five years he has dedicated much of his time and energy into finding out the origin of the celestial body, with interest piquing following the recent publication of his team's academic paper in the scientific journal *Communications Earth & Environment*.

Getting this far has certainly been no easy task. The eccentric entity is no more than 58 metres (190 feet) in diameter, which makes it roughly the size of a Ferris wheel. What's more, the orbiting object is 4 million times fainter than any human could see with the naked eye and about 40 times farther out than the Moon. At its greatest distance it is 25 million miles away, and it gets no closer to Earth than 9 million miles. But there it is, in orbit around Earth and the Sun, albeit following a rather strange path.

"Kamo'oalewa is kind of weaving inside and outside of Earth's orbit as both it and our planet go around the Sun," Sharkey explains, this behaviour resulting from the Sun and Earth's gravitational pulls competing with one another. "If you look at that from the perspective of Earth, it looks like a cork scurrying around the planet in an orbit that doesn't close at any point. It never repeats the same loop in exactly the same way."

The celestial object's odd corkscrew-like orbit certainly caught astronomers' imagination. "We could tell this object had a unique orbit, so there was an immediate interest in characterising it to determine what it's made of and how it is spinning," Sharkey says. "As a student, it seemed like a challenging and interesting project to sink some time into, so we collected a bunch of different kinds of data over a long period of time." Such diligence has been reaping rewards.

There's no doubt that the Arizona study has progressed slowly, but there's been no way of speeding it up. It's only been possible to observe Kamo'oalewa for a few weeks every April, when it was illuminated by the Sun, but astronomers have nevertheless been able to observe the object sufficiently to draw some conclusions. They have been primarily making use of the Large Binocular Telescope on Mount Graham in southern Arizona. The observatory's huge nine-metre (28-foot) mirrors allowed a much closer look at Kamo'oalewa, with observations beginning in 2017.

Backed by data from the Lowell Discovery Telescope, which is a five-hour drive away in

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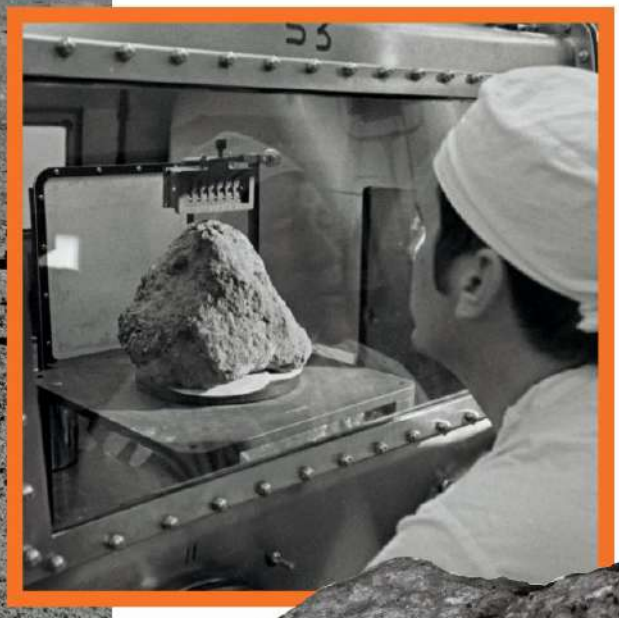


© Alamy

Left: Moon rock samples brought back in the Apollo era have told us much about our lunar companion

Below: 'Big Bertha', the third-largest lunar sample ever collected

© NASA

"KAMO'OALEWA IS KIND OF WEAVING INSIDE AND OUTSIDE OF EARTH'S ORBIT AS BOTH IT AND OUR PLANET GO AROUND THE SUN"

BEN SHARKEY

Flagstaff and funded by NASA's Near-Earth Object Observations Program, the astronomers have been able to monitor Kamo'oalewa's faint infrared signature. The team would make observations, then plan ahead for the following year's window of opportunity, building up a solid bank of knowledge. "Asteroids like this are essentially darker than the sky and fainter than the background glow, so you need large telescopes and infrared instruments to make these detections," Sharkey explains. Slowly but surely, the team's observations and analyses pointed them towards Kamo'oalewa being a lost piece of the Moon.

There's a big reason why this is a major deal. If Kamo'oalewa is indeed a lunar fragment then

PLOTTING KAMO'OALEWA'S ORBIT

How the asteroid became Earth's moon-like buddy

1 ORBITING THE SUN

Kamo'oalewa is also known as 2016 HO3, and just like Earth it orbits the Sun, taking just over a year to do so.

2 STAYING CLOSE

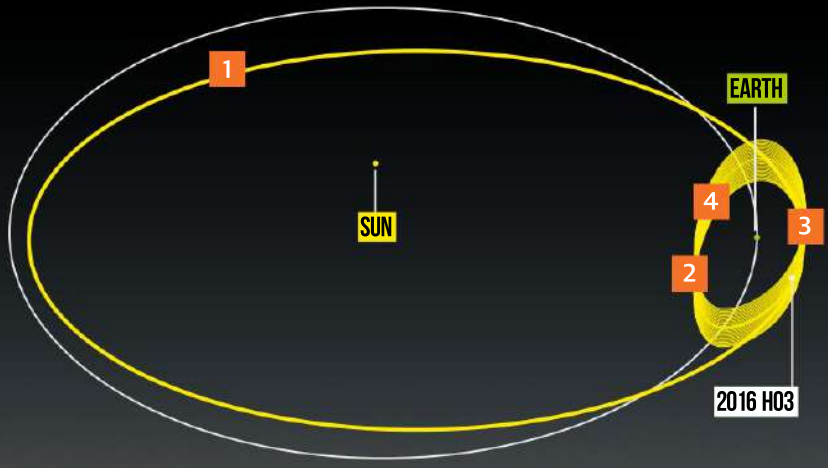
Kamo'oalewa also circles Earth, and it has become a stable quasi-satellite. It doesn't venture too far away as both the asteroid and Earth orbit the Sun.

3 WEAVING IN AND OUT

The asteroid spends roughly half of the time closer to the Sun than Earth; the objects leapfrog so that the other half of the time it is farther away.

4 GRAVITATIONAL PULL

This unusual orbit is due to Earth's gravity being strong enough to hold onto the asteroid. It doesn't venture farther than 100 times the distance of Earth to the Moon.



Pan-STARRS is the world's leading near-Earth object discovery telescope; it picked up on Kamo'oalewa in 2016

Source: Wikipedia commons © Forest & Kim Starr

it would be the only known asteroid with a lunar origin. It also opens up a whole new line of inquiry that explores how the piece came to break away and when it happened. Of course, such events have occurred many times in the past. "You can see craters on the Moon with your own eyes," explains Sharkey. But we think of most asteroids as coming from the asteroid belt.

"We know material from the Moon has been ejected in the past, some of it coming to Earth as meteorites," Sharkey says. "Hundreds of lunar meteorites have been collected on Earth, so impacts on the Moon are not uncommon. But the question is whether we can find a link in the processes. Is there a possibility that material from the Moon that hasn't hit Earth is out there, yet to be found? We could tell a lot about how material has mixed or moved around the Solar System with time."

Sharkey and his team knew early on that Kamo'oalewa wasn't a standard near-Earth asteroid. During observations it wasn't reflecting brightly in particular infrared frequencies, even though it was made of common silicates in the same way as other asteroids. Sharkey sought to match data gathered on Kamo'oalewa with the light reflecting off other near-Earth asteroids. But Kamo'oalewa's dimmer reflection pointed to it being composed of a different material. Researchers just needed to be totally sure there had not been a mistake.

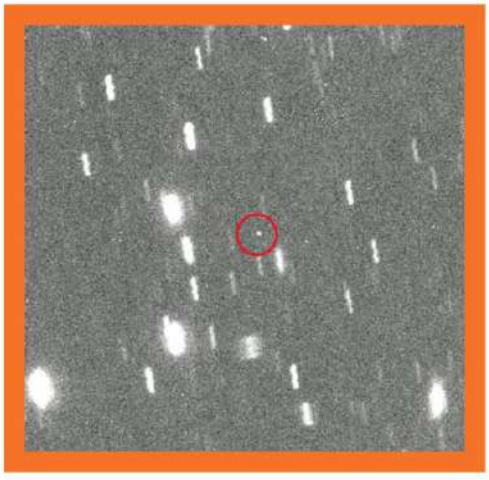
"The spectral signature of some other asteroids can actually look very similar to what Kamo'oalewa looks like at visible wavelengths," Sharkey says. "We had this expectation that it would basically reflect infrared light in a similar way to how it did in the visible, but it displayed a redder reflectance spectrum. We tried to run through different scenarios and think about the different ways to change how asteroids reflect light. This doesn't have to do with just the material it's made of. It could be to do with different textures of the surface – scuffing can make something appear darker or change its colour, for instance, altering how asteroids are reflecting light.

"But we tried to say if we take a more typical asteroid and apply this effect, can we come up with a satisfying answer and achieve a reflection identical to what we saw with Kamo'oalewa? And our argument was that we can't get anything else to work. Then we saw that there's a source of material that has a very good match to this spectrum which is nearby: space-weathered lunar silicates." It opened up a winning line of inquiry.

As luck would have it, one of Sharkey's PhD advisors had studied samples collected from the Fra Mauro formation in the lunar highlands which had been brought back to Earth by the Apollo 14 mission in 1971. "It was a kind of funny moment because he just sort of mentioned it randomly, and it was like, 'hey, you should probably think about this comparison too'," Sharkey laughs. By comparing Kamo'oalewa's pattern of reflected light to those lunar samples, a near-perfect match was found. This suggested that Kamo'oalewa indeed originated from the Moon, with the spectral characteristics being consistent with silicate material showing a high degree of space weathering, such as solar wind particles or micrometeorite bombardment.

Even so, Sharkey and his advisor, University of Arizona associate professor of lunar and planetary sciences Vishnu Reddy, harboured doubts. Although a second set of data was obtained in 2019, they were frustrated that they couldn't observe Kamo'oalewa in 2020 because the COVID-19 pandemic caused the Large Binocular Telescope to be shut down. Fortunately, it was back up and running in April this year, allowing another observation, and this finally convinced the team that they were correct.

But Kamo'oalewa isn't going to hang around. According to the study's coauthor, University of Arizona planetary sciences professor Renu Malhorta, who has been studying the orbit, it will wave goodbye in about 300 years time, once it frees itself from the gravitational ropes that are keeping it around Earth. "It will not remain in this particular orbit for very long, only about 300 years in the future," Malhorta affirms, adding that "it arrived in this orbit about 500 years ago". But what exact path it will take when it goes on its lonely



© EarthSky

Above: Denise Hung and Dave Tholan of the University of Hawaii took this image of Kamo'oalewa on 10 June 2016

> "WE COULD TELL THIS OBJECT HAD A UNIQUE ORBIT, SO THERE WAS AN IMMEDIATE INTEREST IN CHARACTERISING IT"
>
> BEN SHARKEY

THE THEORIES

Astronomers have considered a few explanations for Kamo'oalewa's origin

A CAPTURED ASTEROID

The study's authors examined the possibility that Kamo'oalewa was captured in its Earth-like orbit from the general population of near-Earth objects. But the paper says that simulations of such a scenario don't match the low eccentricity and inclination displayed by Kamo'oalewa.

© Getty

FRAGMENT OF AN ASTEROID

There are two known asteroids that orbit the Sun at the Earth-Sun Lagrangian points L4 and L5. They have similar orbits to Earth's, and it could be that Kamo'oalewa is a split-off piece of one of them, drawn from a quasi-stable population that has yet to be found.

© Alamy

A PIECE OF THE MOON

The recent study of Kamo'oalewa strongly suggests that the asteroid is an ejected fragment of the Moon, probably caused by an impact. This is supported by the reflectance spectrum of Kamo'oalewa being a near-perfect match in comparison to rock samples returned from the Moon.

© Juan A. Sanchez/PSI

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TAP HERE TO PLAY

"IT WILL NOT REMAIN IN THIS PARTICULAR ORBIT FOR VERY LONG, ONLY ABOUT 300 YEARS IN THE FUTURE; IT ARRIVED IN THIS ORBIT ABOUT 500 YEARS AGO"

RENU MALHORTA

adventure is not entirely certain. What we do know, however, is that it's gravitationally bound to the Sun rather than Earth, and that's why it can't actually be classed as a moon, even though it's made up of a bit of one.

"Orbital dynamics are outside my normal expertise," says Sharkey, "but one of the big challenges is tracing the exact path of an object like this beyond a few hundred years. Your uncertainties just become so large that it's really difficult to say anything with confidence besides the sort of general ideas about the state of the object. Beyond 300 years or so, it's a question of the exact path it takes, but it's not going to shoot off in some new direction. It's going to be a more gentle progression than that."

This still gives plenty of time to make more observations, and while there's no chance anyone is going to be thinking of landing a human on this particular 'moon', a sample-return mission to Kamo'oalewa is being planned by the China National Space Administration, with a launch pencilled in for 2025. It's also entirely possible that Kamo'oalewa is not alone, and the orbits of three other near-Earth objects could even be linked. "I feel at this point that anything could be a surprise, or not a surprise, and the honest answer is that we really don't know," Sharkey says. "I think that's part of why this kind of study adds excitement, at least from my perspective. But we didn't really have a good handle on the question of what Kamo'oalewa was beforehand and whether other objects could be related in similar ways. The next step is to keep asking that question."

David Crookes
Science and technology journalist
David has been reporting on space, science and technology for many years, has contributed to many books and is a producer for BBC Radio 5 Live.

Above: An image of the lunar surface taken on the Apollo 14 mission

Right: Kamo'oalewa is roughly the size of Italy's Leaning Tower of Pisa

Source: Wikipedia commons © Saffron Blaze

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ASTROPHYSICS

How do black holes grow in mass?

Once born, black holes can grow by gobbling up gas, other stars or even other black holes. Black holes, particularly supermassive black holes sitting at the centres of galaxies, are often surrounded by gas. They can feed on this gas through an accretion disc – a pancake-like structure of gas that gradually spirals into the black hole. Some massive black holes take their time during this meal, but others go into a feeding frenzy. The rapid, messy eaters in active galactic nuclei try to double their mass over a timescale of around 100 million years, burping out excess energy in powerful jets that are observed as quasars.

Black holes can also pull material from stars that get too close. The black hole's gravity raises tides on a nearby star – like the tides in Earth's oceans, but potentially much stronger. If the tides become too strong, gas from the star flows onto the black hole. This can happen gradually as a stellar companion to a black hole in a binary system evolves and expands in radius, giving rise to black hole X-ray binaries as gas is heated to X-ray-emitting temperatures when it spirals in towards the black hole. Or the entire star can be shredded in one spectacular flare, known as a tidal disruption event. Finally, two black holes can come together and merge, forming a single black hole whose mass is almost equal to the sum of the masses of the original black holes. A small fraction of the mass – around five per cent for equal-mass mergers – is lost in gravitational waves, ripples in space-time predicted by Einstein over a century ago and first detected by the Laser Interferometer Gravitational-wave Observatory (LIGO) in 2015.

Professor Ilya Mandel, Monash University, Australia

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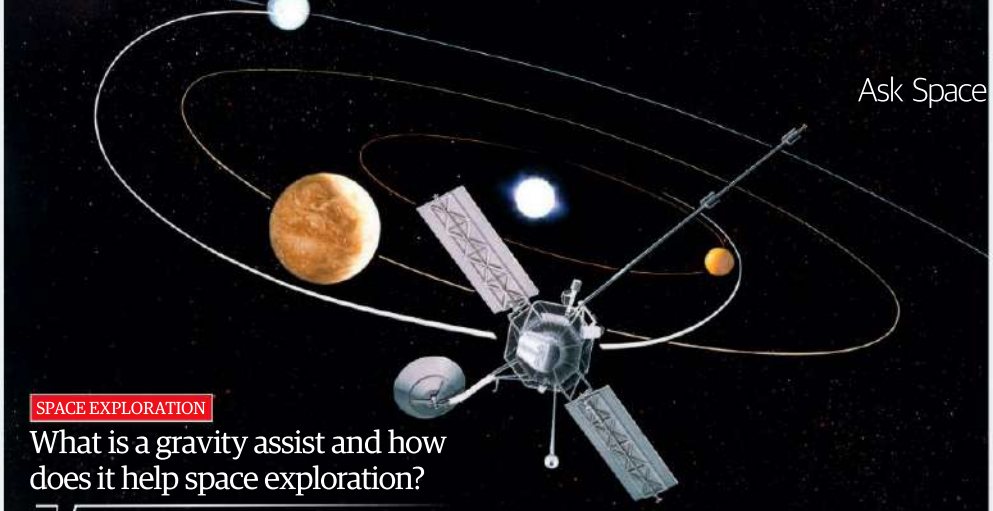
Below: Black holes can fire out excess energy in bright beams called quasars



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SPACE EXPLORATION

What is a gravity assist and how does it help space exploration?

Gravity assists are a clever way to reach far-away planets. Imagine the Solar System as a deep 'well' of gravity, with the Sun at the bottom. Earth is about halfway down. A spacecraft to any other place has to climb down or up the steep walls of the well. Both need lots of energy, so a large rocket is used.

Reaching Mercury, Jupiter, Saturn and beyond would be impossible – even our biggest rockets couldn't send a spacecraft there directly. But scientists have found a solution. Every planet is a big body with a lot of gravity. A spacecraft flying close to a planet will be deflected. This can speed it up, adding energy to its trajectory.

Imagine a tennis racket hitting a ball. Gravity assists work like that – though without actually hitting the planet! For example, instead of flying directly to Saturn, a spacecraft might fly first to Venus, then to Earth, then to Jupiter, picking up energy each time until it has enough to reach Saturn. Gravity assists help space exploration by allowing us to send spacecraft to many places that otherwise we couldn't reach.

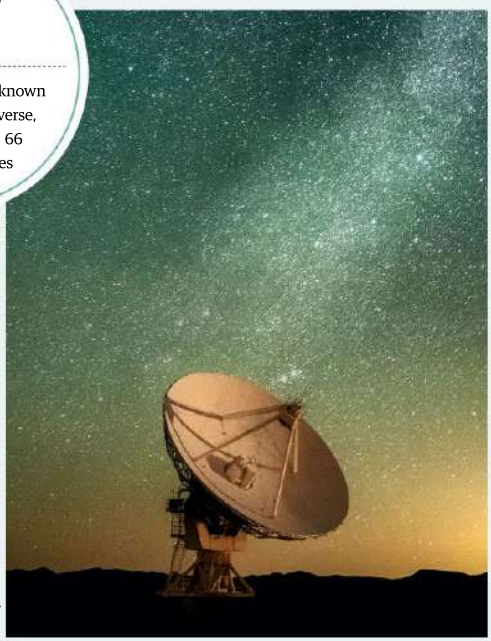
Michael Khan, senior mission analyst, European Space Agency

"A SPACECRAFT FLYING CLOSE TO A PLANET WILL BE DEFLECTED"

MICHAEL KHAN

Did you know?

Ton 618 is the largest known black hole in the universe, estimated to weigh 66 billion solar masses



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Above: Gravity assists allow us to explore more of the Solar System

Right: Radio telescopes are particularly good at searching for alien signals

HUNT FOR LIFE

What is a technosignature?

A technosignature is a signal that would show that we are not the only form of intelligent life in the universe. More precisely, a technosignature is any measurable signal, effect or phenomenon that provides scientific evidence of past or present technology from beyond Earth. The term technosignature comes from the Search for Extraterrestrial Intelligence (SETI). The goal of SETI is to find evidence of intelligent life beyond Earth, or to place meaningful limits on the prevalence of intelligent life. Detecting a technosignature would tell us we are not alone in the universe and would be one of the most profound scientific discoveries ever made.

No compelling technosignatures have been found to date. Breakthrough Listen Candidate 1 (BLC1) is an interesting signal that had many of the characteristics we expect from a technosignature. BLC1 appeared to be coming from the direction of our nearest neighbour, Proxima Centauri, and lasted for over five hours. BLC1 passed all our data quality and interference filters, but after exhaustive analysis we were able to conclude that BLC1 was radio interference from here on Earth. While BLC1 is not a technosignature, it was a fantastic test of our pipelines and helped us create new verification tests for future technosignature candidates.

Dr Danny Price, Breakthrough Listen Initiative, International Centre for Radio Astronomy Research

ASK Space

Our experts answer your questions

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SPACE EXPLORATION

What was your least favourite part of astronaut training? Was there anything it didn't prepare you for?

Learning the Russian language was probably the hardest thing, but I loved it. I hated it, but then I got over the hill and I loved it. The NBL [Neutral Buoyancy Laboratory] can be really fun and satisfying, and it can also be torture. The pool can not be fun because the suits are so bulky. In the early days it was really awful, then towards the end when I got good at it and I knew what I was doing, it got a lot better. I remember after my first run I went and talked to Rex Walheim, the senior astronaut, and I was like, "Rex, this is supposed to be fun?" He laughed and said, "Yes, it sucks. It's terrible, but eventually it gets better".

The training doesn't prepare you for the view – it's so spectacular. Words cannot describe what it's like to see that with your own eyes. I've tried to describe it and show it, but until you see it, the visual impact of looking out at Earth, it's really amazing.

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Terry Virts, former NASA astronaut

© JAXA

SOLAR SYSTEM

Why do we have to look at asteroids in space rather than breaking open a meteorite on Earth?

Meteorites bombard us every day, and we've collected thousands on Earth. They're available in a much larger amount – not just tiny specks, but large chunks – so you've got a lot more material to study. We've learnt so much about organics and water from meteorite studies, but there's one problem. Because all meteorites are recovered on Earth, you don't know how much terrestrial contamination they've been exposed to. Some are recovered as 'fall meteorites', so people see when and where they fell and study them as soon as they can. But the meteorites are still contaminated.

The sample my team studied from Itokawa was collected by the first Hayabusa, a mission dedicated to go to an asteroid and bring back a sample for analysis. In terms of contamination, this is a much cleaner sample. This was especially important because we were going to look at water and organics, which are abundant on Earth, and we didn't want contamination. We also know where the sample has come from; we know that it's an asteroid that has been sitting in its orbit around the Sun and what the orbit looks like. We've got a lot more context about the origin of the sample, rather than just a rock that we know is from outer space and has fallen to Earth.

Dr Queenie Hoi Shan Chan, planetary scientist, Royal Holloway

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SOLAR SYSTEM

Why isn't Earth a perfect sphere?

Earth isn't a perfect sphere for two main reasons. The first is that the material of Earth possesses strength unlike a simple fluid. This strength is enough to overcome the forces of gravity to some extent. If Earth was a simple fluid, it would assume the shape of minimum energy – a perfect sphere – provided Earth didn't spin on its axis. However, Earth does spin on its axis. The spin provides a force that acts against the force of central gravity, giving Earth a slightly flattened shape – the equatorial radius is about 30 kilometres (18.6 miles) greater than the polar radius. Even if Earth was a spinning ball of fluid with no strength, unlike rocks, it wouldn't be a sphere – it would have the shape of a prolate ellipsoid.

Professor Emeritus Frank J. Spera, Department of Earth Science, University of California, Santa Barbara

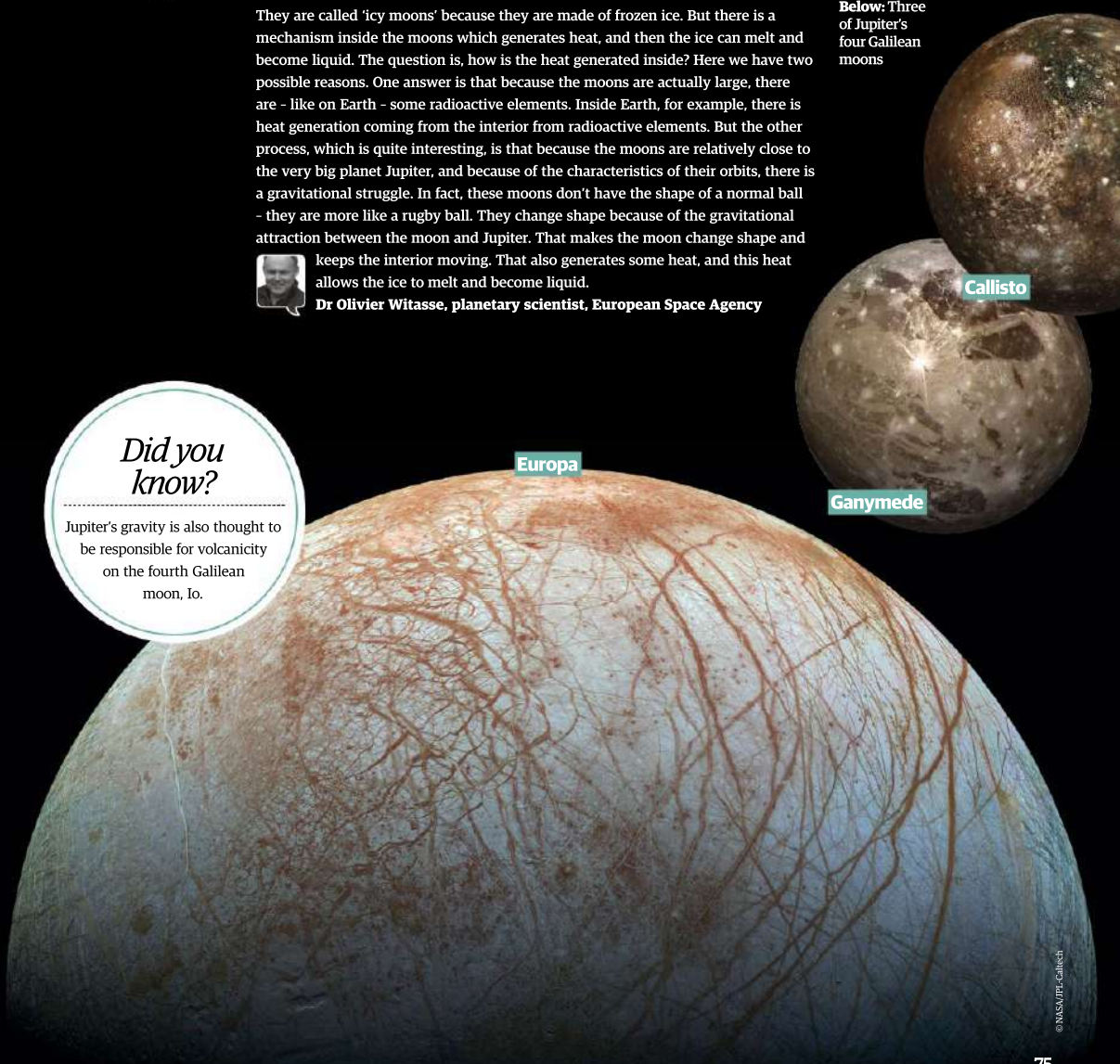
SOLAR SYSTEM

How have the moons Ganymede, Callisto and Europa sustained a subsurface ocean despite being so far away from the Sun?

They are called 'icy moons' because they are made of frozen ice. But there is a mechanism inside the moons which generates heat, and then the ice can melt and become liquid. The question is, how is the heat generated inside? Here we have two possible reasons. One answer is that because the moons are actually large, there are – like on Earth – some radioactive elements. Inside Earth, for example, there is heat generation coming from the interior from radioactive elements. But the other process, which is quite interesting, is that because the moons are relatively close to the very big planet Jupiter, and because of the characteristics of their orbits, there is a gravitational struggle. In fact, these moons don't have the shape of a normal ball – they are more like a rugby ball. They change shape because of the gravitational attraction between the moon and Jupiter. That makes the moon change shape and keeps the interior moving. That also generates some heat, and this heat allows the ice to melt and become liquid.

Dr Olivier Witasse, planetary scientist, European Space Agency

Below: Three of Jupiter's four Galilean moons



Did you know?

Jupiter's gravity is also thought to be responsible for volcanicity on the fourth Galilean moon, Io.

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WHAT'S WRONG WITH MY TELESCOPE?

THERE ARE SOME COMMON PROBLEMS YOU MIGHT FIND YOURSELF FACED WITH WHEN OBSERVING. HERE'S HOW TO DEAL WITH THEM

PROBLEM

I CAN'T SEE ANYTHING

It's not cloudy and you've ensured that your telescope's objective lens and finderscope caps are off, but you're still struggling to see your chosen target. If you're having difficulty seeing anything through your telescope, then one or more of the following could be to blame.

OPTION 1

YOUR TELESCOPE MIGHT NOT BE COLLIMATED PROPERLY

When a telescope is collimated properly, all of its mirrors or lenses are aligned. When they aren't lined up, then light from the object you're looking at can't be reflected or refracted in such a way that you can see the object through your eyepiece.

SOLUTION

Schmidt-Cassegrain telescopes and reflectors can usually be collimated with ease, at least once you know what you're doing. However, unless you're an optical expert, we wouldn't advise trying to align the lenses in a refractor. Remember, if you're unsure of how to collimate your instrument, it's best to err on the side of caution and take it to an expert who knows how.

OPTION 2

YOU MIGHT NOT BE DARK ADAPTED

While it's true that you can see some brighter targets as soon as you head outside – and even under moderately light-polluted skies – it's not true for the fainter stars and planets, even through a telescope.

SOLUTION

This is a rookie mistake to make, but fortunately one that's easily corrected with minimal experience. You should wait for your eyes to adapt to the dark before trying to view the night sky. This usually takes around 20 minutes. If you need to use a torch, ensure that it emits red light rather than white.

OPTION 3

YOU MIGHT NOT BE AIMING AT ANYTHING

It seems like a silly mistake to make, but you might find that your telescope isn't pointing at anything in particular other than a patch of dark sky, devoid of any bright objects.

SOLUTION

Simply make sure you're pointing your telescope at a bright target, at the very least to check if there isn't something more serious afoot. A good example of one is the Moon – if it's out on the night you have chosen to do your observations and viewing.

PROBLEM

MY TARGET KEEPS MOVING OUT OF VIEW

If your telescope is kept motionless, due to the Earth's rotation objects will move out of view. If, on the other hand, your telescope moves up and down when you let go of it after aligning, your instrument could be suffering from poor tube balance or a mount that's unable to support your tube.

SOLUTION

Telescopes from supermarkets and online retailers often suffer from poor mounting. If tightening your mount doesn't work, replacing it for a mount that's capable of holding your telescope's tube is an option.

PROBLEM

I CAN'T FIND ANYTHING

It's easy to forget how small a telescope's field of view can be, even if the magnification is low. The telescope can only see a small piece of the sky, so it's fairly easy to be spending most of the night trying to line up your telescope.

SOLUTION

If you don't own a GoTo to help you find objects, you should use your telescope's guide scope or finderscope, provided this has been aligned correctly. You can also look along the end of your instrument's tube to get an idea of how it should be aligned in order to view your target. The Moon at a low magnification is your best bet at solving this problem.

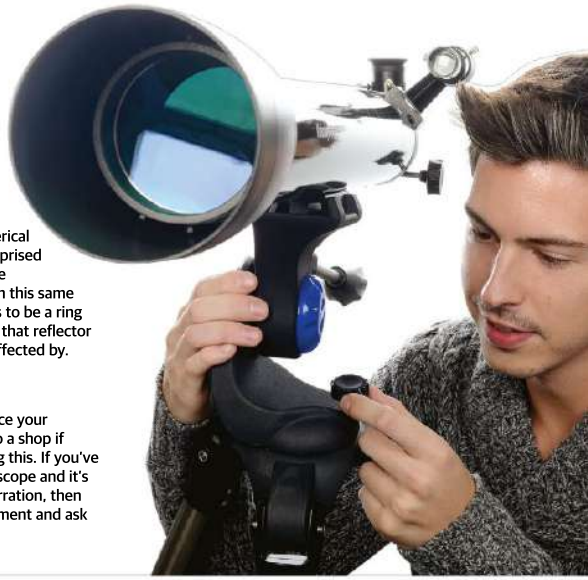
PROBLEM

I CAN'T GET THE ENTIRE VIEW INTO FOCUS

This is what's known as spherical aberration. You might be surprised to learn that even the Hubble Space Telescope suffers from this same problem, where there seems to be a ring of best focus. It's something that reflector telescopes are particularly affected by.

SOLUTION

The only real cure is to replace your telescope's mirror – take it to a shop if you're not comfortable doing this. If you've purchased a brand-new telescope and it's suffering from spherical aberration, then you should return the instrument and ask for a refund or replacement.



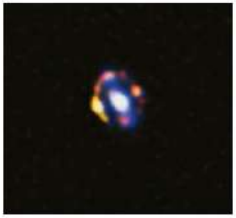
PROBLEM

EVERYTHING LOOKS BLURRY

No matter what you look at, your target looks like a massive blob with no definite appearance. Whatever you look at through your telescope, it should appear crisp and clear. For example, the Moon's craters should appear well defined, while objects such as stars and planets should take a 'point-of-light' appearance.

SOLUTION

Check and adjust the focuser of your telescope to see if you can bring the object into focus. If this doesn't work, it could be that your optics are dirty, so ensure that your eyepiece is clean. If you've cleaned your optics and you're still having issues, it could be that the eyepiece that you're using is defective, so try to use a different eyepiece to see if that fixes the problem.



© NASA

PROBLEM

COLOUR FRINGED BRIGHT OBJECTS

Faint blue or violet-coloured halos occur when the blue component of light doesn't focus at exactly the same point as the other colour components. Called chromatic aberration, this usually happens when you look at brighter objects such as the Moon. It's also more common in refractors.

SOLUTION

Colour fringing cannot be reduced. The good news is that you can remove chromatic aberration in Photoshop or a similar photo-editing software if you're an astrophotographer. If this is something that bothers you, either go for an apochromatic refractor, reflector or Schmidt-Cassegrain, which should clear up your night-sky observation sessions.

Source: Wikipedia Commons © Brocken Inaglory

PROBLEM

STARS SHIFT OR GROW TAILS

This is known as coma. If your target is changing shape when you focus, then your telescope may be suffering from astigmatism – that's when one or more of the optical components are not perfectly symmetrical. It can also happen when there's a bit of pressure on the optical components.

SOLUTION

You can buy accessories to correct coma, but you might find that these are quite expensive. If you own a reflector then you should check that nothing is pushing down on your instrument's mirrors and warping them slightly. Alternatively, if the astigmatism is severe, you should replace the troublesome component. If your instrument is new, ask for a refund.

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WHAT'S IN THE SKY?

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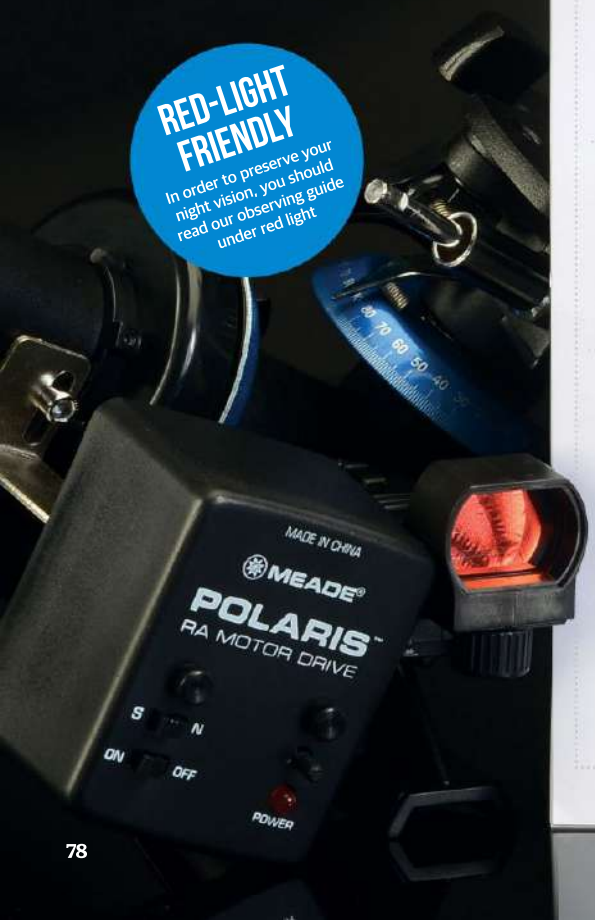


RED-LIGHT FRIENDLY
In order to preserve your night vision, you should read our observing guide under red light

28 DEC
Open star cluster NGC 2232 is well placed for observation in Monoceros

29 DEC
Open star cluster NGC 2244 is well placed for observation in Monoceros

31 DEC
The Moon will pass in front of Mars, creating a lunar occultation visible from parts of Australia

6 JAN
The Moon and Jupiter make a close approach, passing within 4°09′ of each other in Aquarius

7 JAN
Mercury is at its greatest elongation in the evening sky, shining at magnitude -0.6

9 JAN
Mercury reaches half phase (dichotomy) in the evening sky

12 JAN
Comet 104P/Kowal is predicted to reach its brightest magnitude of at least +9.0 in Cetus

13 JAN
Asteroid 7 Iris reaches opposition, glowing at magnitude +7.7 in Gemini

15 JAN
Open star cluster Messier 47 is well placed for observation in Puppis

19 JAN
The Gamma Ursae Minorid meteor shower reaches its peak

20 JAN
Comet 19P/Borrelly is predicted to reach its brightest magnitude of at least +8.9 in Cetus

JARGON BUSTER

Conjunction
This is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Declination (Dec)
Declination tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Right Ascension (RA)
Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

Magnitude
An object's magnitude tells you how bright it is from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object will be. So, an object with a magnitude of -1 is brighter than an object with a magnitude of +2.

Greatest elongation
This is when the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as bright evening stars during greatest eastern elongations and as morning stars during western elongations.

Opposition
This is when a celestial body is in line with the Earth and the Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter in the sky.

3 JAN
The Quadrantid meteor shower reaches its peak

4 JAN
Earth reaches perihelion

6 JAN
Conjunction between the Moon and Jupiter in Aquarius

10 JAN
C/2019 L3 (ATLAS) reaches perihelion and is predicted to reach +9.7 in Gemini

12 JAN
Comet 104P/Kowal reaches perihelion and is predicted to reach +9.0 in Cetus

12 JAN
Mercury reaches its highest point in the evening sky, shining at magnitude -0.6

© ESA

15 JAN
Spiral galaxy NGC 2403 is well placed for observation in Camelopardalis

18 JAN
Uranus ends its retrograde motion

29 JAN
The Moon and Mars pass within 2°24′ of each other in Sagittarius

29 JAN
Conjunction between the Moon and Mars in Sagittarius

- Naked eye
- Binoculars
- Small telescope
- Medium telescope
- Large telescope

STARGAZER

PLANETARIUM

12 JANUARY 2022

OPPOSITION EVENING SKY

MOON CALENDAR

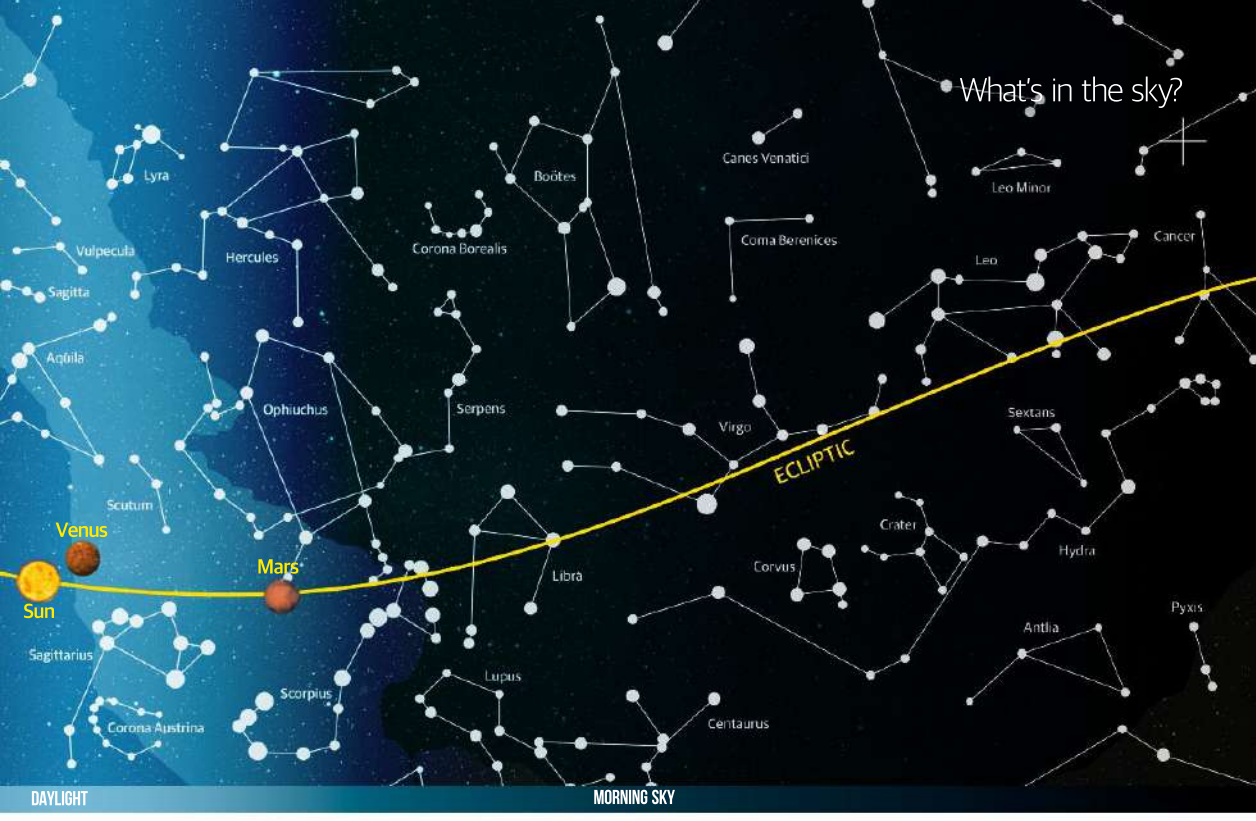
* The Moon does not pass the meridian on 17 January

30 DEC 16.4% 03:56 13:12	31 DEC 8.3% 05:26 13:41	1 JAN 2.7% 06:54 14:23	2 JAN NM 0.2% 08:13 15:22	3 JAN 1.0% 09:14 16:38	4 JAN 4.9% 09:58 18:03	5 JAN 11.5% 10:28 19:30
6 JAN 19.9% 10:50 20:54	7 JAN 29.5% 11:07 22:13	8 JAN 39.7% 11:21 23:28	9 JAN FQ 50.1% 11:34 --:--	10 JAN 60.1% 00:40 11:48	11 JAN 69.5% 01:52 12:03	12 JAN 78.0% 03:02 12:20
13 JAN 85.5% 04:13 12:41	14 JAN 91.6% 05:22 13:09	15 JAN 96.1% 06:27 13:45	16 JAN 98.9% 07:24 14:33	17 JAN FM --:--%* 08:11 15:31	18 JAN 99.9% 08:48 16:39	19 JAN 98.8% 09:16 17:51
20 JAN 95.6% 09:38 19:06	21 JAN 90.5% 09:55 20:22	22 JAN 83.5% 10:10 21:37	23 JAN 74.9% 10:25 22:54	24 JAN 64.8% 10:39 --:--	25 JAN TQ 53.8% 00:13 10:55	26 JAN 42.3% 01:35 11:13
27 JAN 30.9% 03:01 11:38						

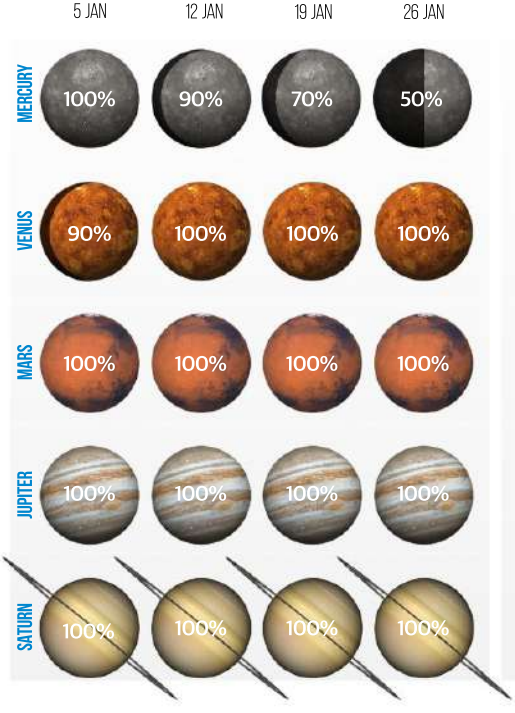
% Illumination
Moonrise time
Moonset time

FM Full Moon
NM New Moon
FQ First quarter
TQ Third quarter

All figures are given for 00h at midnight (local times for London, UK)



ILLUMINATION PERCENTAGE



PLANET POSITIONS

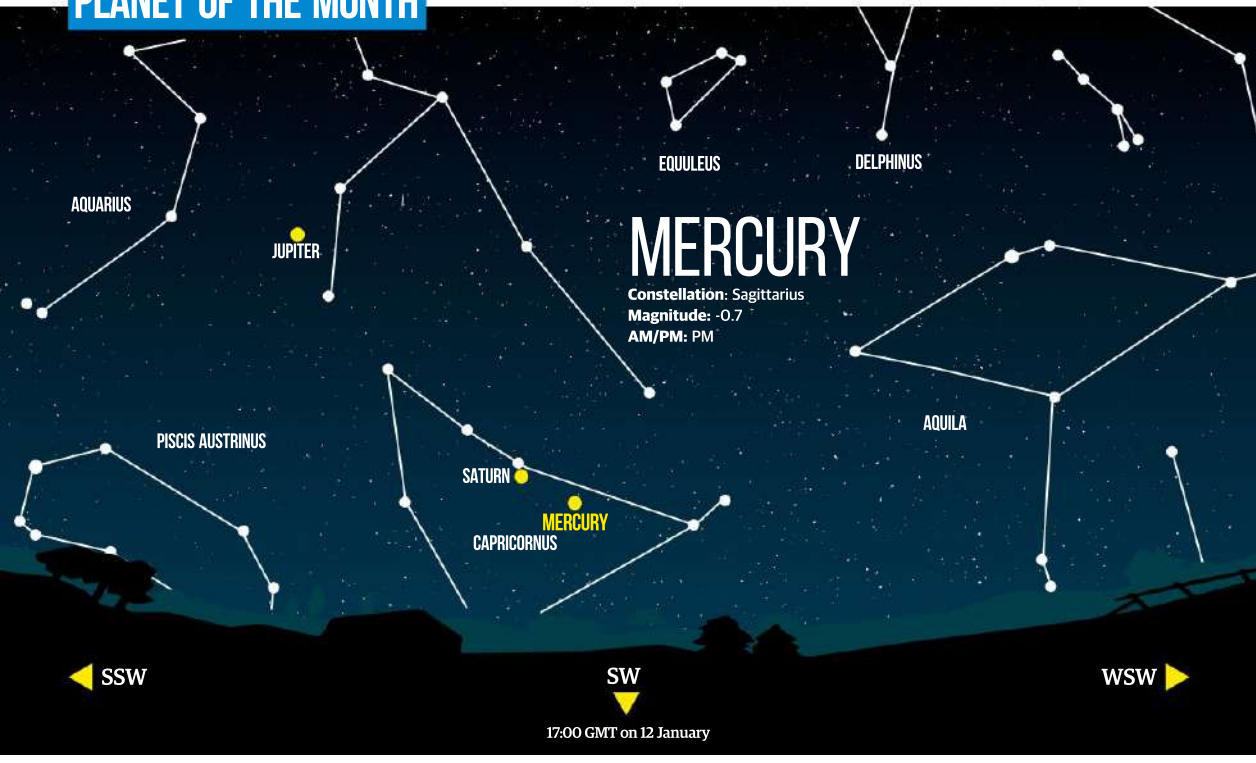
All rise and set times are given in GMT

DATE	RA	DEC	CONSTELLATION	MAG	RISE	SET
30 DEC	19h 49m 11s	-23° 05' 16"	Sagittarius	-0.7	09:21	17:13
5 JAN	20h 23m 23s	-20° 43' 11"	Capricornus	-0.7	09:16	17:40
12 JAN	20h 47m 24s	-17° 42' 00"	Capricornus	-0.2	08:50	17:51
19 JAN	20h 39m 28s	-16° 02' 09"	Capricornus	+2.5	08:04	17:23
26 JAN	20h 04m 58s	-16° 42' 45"	Sagittarius	+3.9	07:07	16:16
30 DEC	19h 41m 23s	-18° 59' 45"	Sagittarius	-4.3	08:43	17:28
5 JAN	19h 27m 38s	-17° 57' 27"	Sagittarius	-4.1	08:01	16:58
12 JAN	19h 09m 16s	-16° 59' 30"	Sagittarius	-4.1	07:06	16:15
19 JAN	18h 53m 49s	-16° 23' 24"	Sagittarius	-4.4	06:21	15:36
26 JAN	18h 45m 32s	-16° 11' 15"	Sagittarius	-4.5	05:45	15:01
30 DEC	16h 39m 15s	-22° 15' 02"	Ophiuchus	+1.5	06:06	14:06
5 JAN	16h 57m 34s	-22° 50' 17"	Ophiuchus	+1.5	06:06	13:59
12 JAN	17h 19m 13s	-23° 21' 41"	Ophiuchus	+1.5	06:01	13:47
19 JAN	17h 41m 09s	-23° 42' 06"	Ophiuchus	+1.5	05:59	13:41
26 JAN	18h 03m 18s	-23° 51' 09"	Sagittarius	+1.4	05:53	13:32
30 DEC	22h 09m 14s	-12° 27' 25"	Aquarius	-2.2	10:36	20:35
5 JAN	22h 13m 44s	-12° 01' 56"	Aquarius	-2.1	10:15	20:19
12 JAN	22h 19m 14s	-11° 30' 33"	Aquarius	-2.1	09:47	19:57
19 JAN	22h 24m 57s	-10° 57' 34"	Aquarius	-2.1	09:24	19:39
26 JAN	22h 30m 50s	-10° 23' 11"	Aquarius	-2.1	09:00	19:22
30 DEC	20h 56m 19s	-18° 09' 11"	Capricornus	+0.7	09:55	18:48
5 JAN	20h 58m 57s	-17° 58' 27"	Capricornus	+0.7	09:31	18:27
12 JAN	21h 02m 08s	-17° 45' 22"	Capricornus	+0.7	09:08	18:07
19 JAN	21h 05m 24s	-17° 31' 45"	Capricornus	+0.7	08:41	17:42
26 JAN	21h 08m 44s	-17° 17' 43"	Capricornus	+0.7	08:14	17:18

THIS MONTH'S PLANETS

The far-flung ice giants make for easy pickings as we ring in the New Year

PLANET OF THE MONTH

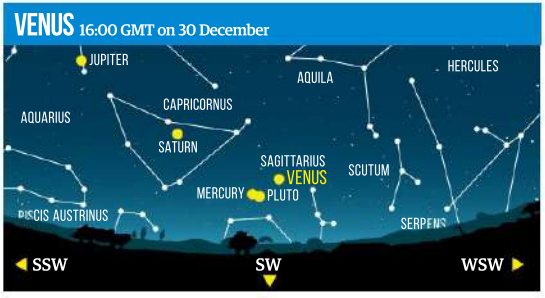


Mercury is our planet of the month this issue, not just because it will be bright and easy to see after sunset, but because there will be so much going on around it in the sky. Mercury is often described as being elusive and hard to see, and it's true that a surprising number of amateur astronomers have never seen it, but in reality it's not really that hard to see. Although it never shines as brightly as Venus, little Mercury is easy to see with the naked eye when it is at its best, and once you've found it you'll find your eye can pick it out again very easily.

Mercury is challenging to see because it is the closest planet to the Sun, so it never appears to stray very far from the Sun in the sky. Consequently, we only ever see Mercury in the twilight for a short time, sometimes before sunrise and sometimes after sunset. This month Mercury will be an evening star, and although it will be bright enough to be clearly visible to the naked eye, it will be low in the sky to the southwest, so you'll need to have a clear horizon in that direction to see it properly.

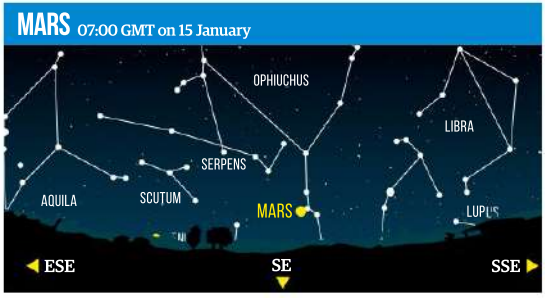
At the start of our observing period Mercury will lie in the constellation of Sagittarius and will be visible as the sky darkens after sunset as a copper-hued 'star' less than five degrees to the lower left of much brighter Venus, and down to the lower right of Saturn too. As the days pass, Mercury will appear to move away from Venus and climb up towards Saturn, crossing the border into Capricornus as it does.

By 3 January Mercury will lie between Saturn and Venus, the three worlds forming a very pretty chain of three stars stretched across the twilight, with Jupiter extending that chain further to the upper left. On the following evening of 4 January, you'll be able to see a beautiful, fingernail-clipping-thin crescent Moon shining to the left of Mercury, and this gathering of the Moon and planets in the twilight will definitely be worth photographing if you have the right equipment – even the camera on your phone should be good enough to capture this beautiful planetary gathering.



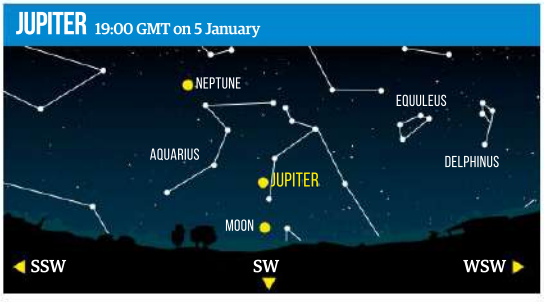
Constellation: Sagittarius **Magnitude:** -4.3 **AM/PM:** PM

Venus will be a bright 'evening star' this month, easily visible to the naked eye as a bright spark of light low in the southwest soon after sunset. At the end of December you'll be able to see it shining a short distance to the upper left of fainter Mercury before the pair set around an hour and a half after the Sun.



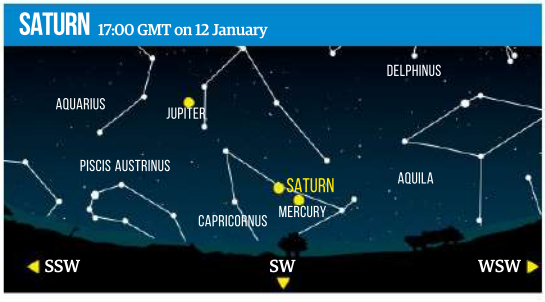
Constellation: Ophiuchus **Magnitude:** +1.5 **AM/PM:** AM

Mars will be visible in the morning sky during the month ahead. At the start of January it will be shining at magnitude +1.5, so it will be easily visible to the naked eye as an orange 'star'. By mid-January Mars will be joined in the predawn eastern sky by much brighter Venus as it moves across the border of Ophiuchus and into the constellation of Sagittarius.



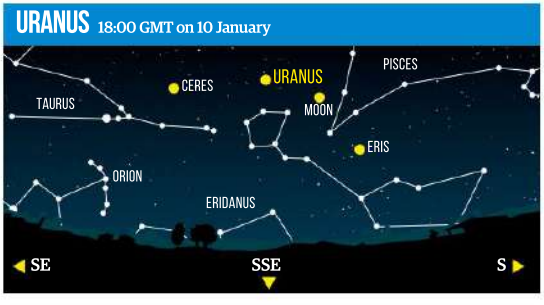
Constellation: Aquarius **Magnitude:** -2.1 **AM/PM:** PM

You'll see Jupiter shining quite high in the south as soon as the sky begins to darken, and although it's now past its period of greatest visibility, you'll still have plenty of time to see it. At the start of January it will be setting four hours after the Sun, and at month's end you'll still have two hours to see it after sunset.



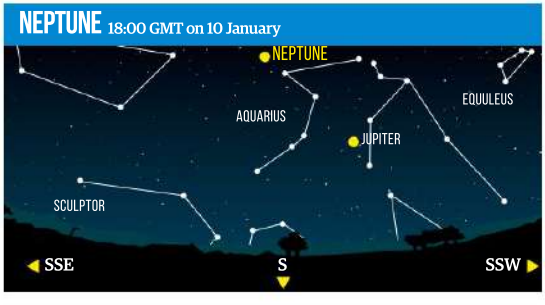
Constellation: Capricornus **Magnitude:** +0.7 **AM/PM:** PM

Saturn will be visible in the evening sky to the southwest all through January. It will look like a yellow-white star to the lower right of brighter, bluer Jupiter, and will lie to the upper left of brighter Venus. In January Saturn will have a close encounter of the planetary kind with Mercury as the two worlds appear to come close together in the evening twilight.



Constellation: Aries **Magnitude:** +5.7 **AM/PM:** PM

This month Uranus will be visible all night and into the early hours. As the Sun sets it will already be high in the east, and it will then slowly arc eastwards through the night, reaching its highest in the south around midnight. Shining at +5.7, Uranus will technically be visible to the naked eye, but you'll need a good star chart and no light pollution to find it.



Constellation: Aquarius **Magnitude:** +7.9 **AM/PM:** PM

Neptune will be an evening object this month, visible after sunset high in the south. Neptune is far too faint to be visible to the naked eye because it is so far away from the Sun - and us - that it takes 165 Earth years to orbit our star once. You'll need binoculars or a telescope if you want to see this faraway world, and even then it will only look like a tiny, blue-green star.

© NASA

MOON TOUR

MENELAUS CRATER

How to find the impact at the end of one of the longest rays on the Moon

Many well-known craters are famous for being at the centre of complicated systems of rays. When they were formed, Copernicus, Tycho and Aristarchus all splashed bright rays of debris huge distances across the lunar surface. Elsewhere on the Moon, smaller, lesser known craters have systems of rays too, and one of them, Menelaus, is the source of possibly one of the longest and brightest rays on the Moon.

Menelaus is small, just 27 kilometres (17 miles) across and barely three kilometres (1.9 miles) deep, but when the Moon's phase is just right, it's easily visible in binoculars and small telescopes. Slightly oval in shape, it lies on the edge of the low Montes Haemus, a curving mountain range that can be found on the southern shore of the Sea of Serenity.

Through binoculars the crater is unremarkable, little more than a sharp-edged pit blasted out of the ground, looking like the hole a nuclear warhead would leave behind in a science-fiction film. But no warhead created Menelaus; the crater was blasted out of the Moon by a chunk of Solar System debris. The object came in at a shallow angle, resulting in the crater's oval shape. The impact scattered debris all around the crater, creating smaller secondary craters.

Menelaus also seems to be the source of a single, bright and very long ray that stretches away from it and crosses the whole of the Sea of Serenity, but even though the crater and the ray line up perfectly, there's still a lot of debate about their relationship.

Known by some observers as 'the Bessell Ray' because it appears to be superimposed over the small crater Bessell, which lies to the northeast of Menelaus, this ray is a striking sight at full Moon and is easily visible in binoculars. The mystery of the ray's origins probably won't be solved until robot probes or human explorers land on the Moon and can directly compare the ray's material to the material inside Menelaus.

Through a small telescope, Menelaus itself shows some interesting detail. Its inner walls are subtly terraced, with multiple small, narrow ledges, and its floor is very hummocky, with many mounds and hills there to observe. If the Moon is in the right phase, a telescope will also allow you to see a network of fascinating cracks and troughs in the flat, grey plain of the Sea of Serenity just to the northeast of Menelaus, known as 'Rimae Menelaus' – 'rimae' means gaps, or fissures. At low magnification they look like scratches on the Moon. Higher magnifications at the right phase show a complicated network of criss-crossing features, small pits and troughs.

On 16 January the Moon will be full, so Menelaus will be fully illuminated by the Sun, looking like a bright 'spot' on the southern end of Mare Serenitatis at around the seven o'clock position before looking like a pit again as the Sun sinks lower in the sky. On 23 January, the terminator – the line between lunar day and night – will start to pass across the crater, and it will have vanished from view the following day. Menelaus will then be in total darkness for two long weeks before it reappears on 6 February as the terminator approaches it once more. The crater will be in full sunlight again by 10 February, and will remain visible until the Moon is full again.

There are plenty of opportunities to turn your telescope, binoculars or unaided eye to the crater throughout the next few weeks. However, the very best time to see Menelaus will be between 8 and 23 January, and again between 7 and 22 February, because that's when sunlight will be striking it at a low angle, making it stand out starkly against the Moon's grey-white surface.

TOP TIP!

Look for Menelaus when it's close to the terminator. That's when the crater and its surroundings will look their best.

NAKED EYE & BINOCULAR TARGETS

January's sky is a treasure trove of bright stars and glittering star clusters

1 Mizar and Alcor
Look closely at the star Mizar in the centre of the Big Dipper's curved handle and you'll see it is actually a pair of stars. Mizar's much fainter companion is Alcor. This famous double star is known by some as 'the Horse and Rider'.

2 Beehive Cluster (Messier 44)
Messier 44, also dubbed the Beehive Cluster or Praesepe, is an open star cluster in the middle of the constellation of Cancer, the Crab. A smudge to the naked eye, binoculars and telescopes reveal it is a group of almost 1,000 stars, one-and-a-half times as wide as the Moon. The easiest way to find Messier 44 is by drawing a line from Pollux in Gemini to Regulus in Leo.

3 Sickle of Leo
'The Sickle' is the name given to the stars representing the head of Leo, the Lion. It looks like a back-to-front question mark in the sky, or the hook of a coat hanger. Since it's close to the ecliptic, bright planets can often be seen in or near the Sickle.

4 Arcturus (Alpha Boötis)
Shining at magnitude -0.05, red giant Arcturus is the fourth-brightest star in the sky and the brightest in the Northern Celestial Hemisphere. It is just over 36 light years away, and is found by following the curve of the Big Dipper's handle.

5 Regulus (Alpha Leonis)
Blue-white Regulus is 79 light years away and is the 21st-brightest star in the sky, with a magnitude of +1.35. In Latin its name means 'Little King'. Although the naked eye sees Regulus as a single star, it's actually two stellar pairs orbiting each other, which can be split into two by amateur telescopes.

URSA MAJOR

LEO

BOÖTES

Hubble's Variable Nebula (NGC 2261)

Source: Wikipedia Commons © Judy Schmidt

DEEP SKY CHALLENGE

OBSERVE THE UNICORN'S SPARKLING TREASURES

Winter skies are rich in deep-sky objects for your telescope to hunt down and enjoy. Here are just a select few

Just to the east of the constellation of Orion (the Hunter) is a dimmer constellation called Monoceros (the Unicorn). Although none of the stars that make up the group are particularly bright, this constellation sits in the band of the Milky Way, and is therefore rich in nebulae and star clusters.

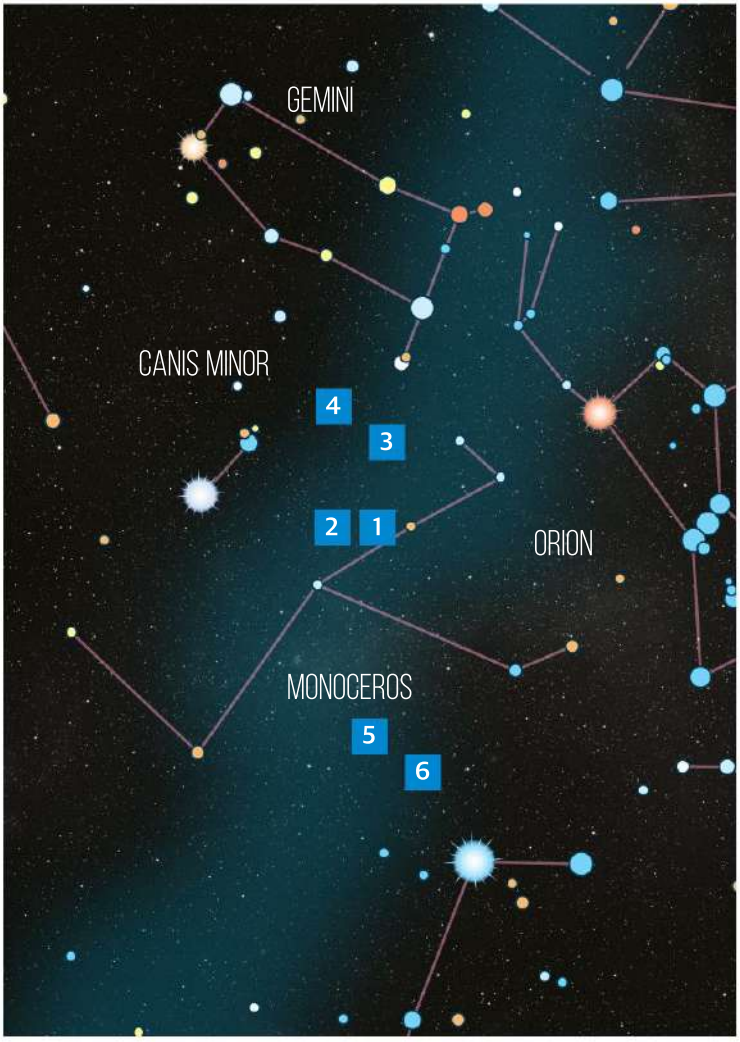
It contains some fairly well-known objects, such as the Cone Nebula, the more famous Rosette Nebula and Hubble's Variable Nebula; this is a rich region of the sky to go exploring with a telescope of almost any size.

Christmas Tree Cluster (NGC 2264)

© ESO

Seagull Nebula (IC 2177)

© ESO



Deep sky challenge

1 Rosette Nebula (NGC 2238)

The Rosette Nebula is a tricky target to see visually. However, with the right equipment – namely a larger aperture and very good observing conditions – it opens up to reveal a fine cluster at the heart of luminous gas and dust.

2 Satellite Cluster (NGC 2244)

You can pick up this loose collection of stars with a pair of binoculars, but for more comfortable views use a small telescope to pick out the gaggle of blue stars, shining at a collective magnitude of +4.4.

3 Hubble's Variable Nebula (NGC 2261)

You'll need a four-inch telescope in order to spot this mysterious-looking object. The nebula itself is like a hollow shell, but see if you can spot light and dark knots using a high-power eyepiece.

4 Cone Nebula (NGC 2264)

Since the Cone Nebula is a challenging target given its feeble glow, dark skies and a large telescope are needed. The nebula lies in the southern portion of the Christmas Tree Cluster (NGC 2264).

5 Heart-Shaped Cluster (Messier 50)

This is an open star cluster that, as its name suggests, appears to have the shape of a heart. A small telescope will reveal the cluster's heart shape, while larger apertures will tease out blue-white, yellow and orange stars.

6 Seagull Nebula (IC 2177)

This nebula is best seen in large-aperture telescopes, and a UHC filter can help increase the contrast. This H II region lies on the border of Monoceros and Canis Major, covering over three degrees of sky.

"THIS IS A RICH REGION OF THE SKY TO GO EXPLORING WITH A TELESCOPE OF ALMOST ANY SIZE"

THE NORTHERN HEMISPHERE

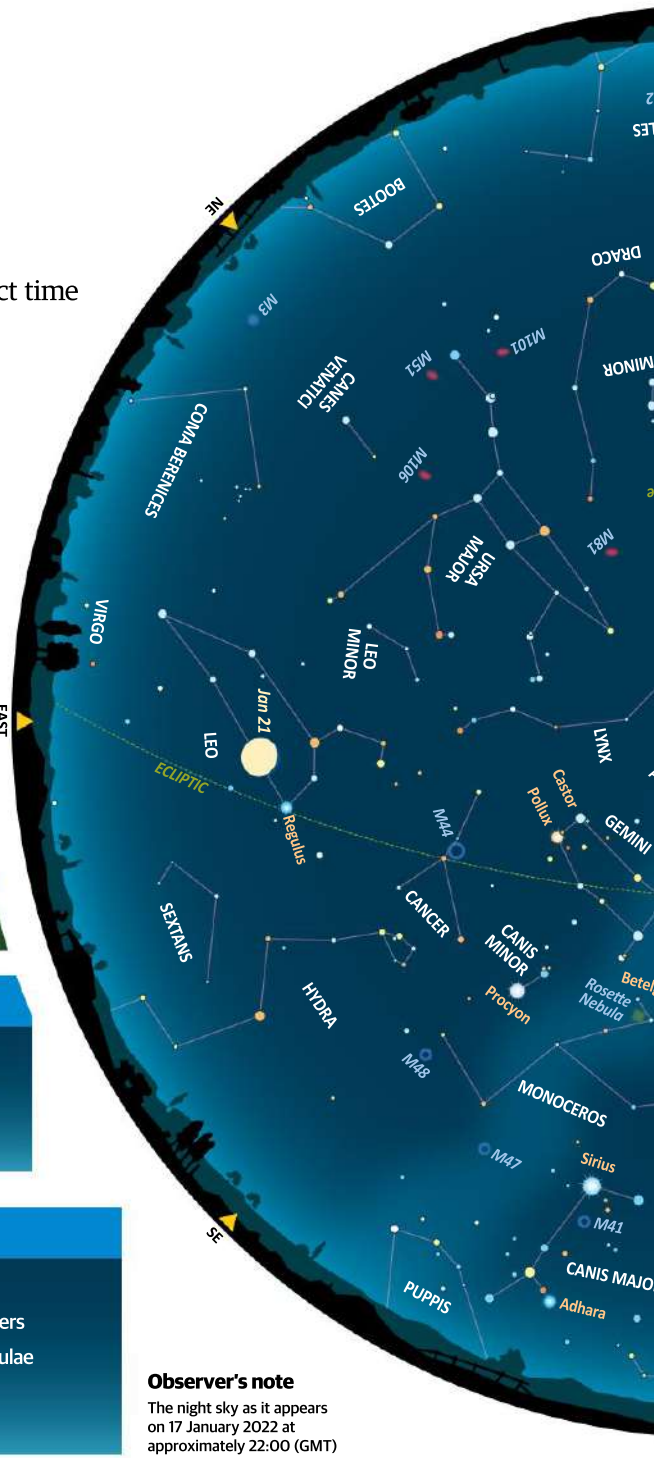
The middle of the darker months is the perfect time to turn your telescope to the skies

The midst of winter offers a selection of targets not just for the beginner to whet their stargazing appetite, but for seasoned sky-watchers to get truly stuck into. Mid-January through to February offers a selection of star clusters, galaxies and nebulae for those armed with or without an optical aid. These views complement the readily available planets, which observers will see make their grand appearances at dusk and dawn through the coming weeks. The Cigar Galaxy (Messier 82), bursting with star formation in the constellation of Ursa Major, as well as M106, M94 and M63 in the constellation of Canes Venatici and the star clusters of Gemini, Orion and Perseus, are readily available for viewing.

USING THE SKY CHART

This chart is for use at 22:00 mid-month and is set for 52° latitude.

1. Hold the chart above your head with the bottom of the page in front of you.
2. Face south and notice that north on the chart is behind you.
3. The constellations on the chart should now match what you see in the sky.



Observer's note

The night sky as it appears on 17 January 2022 at approximately 22:00 (GMT)

MAGNITUDES

- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- Fainter
- Variable star

SPECTRAL TYPES

- O-B
- A
- F
- G
- K
- M

DEEP-SKY OBJECTS

- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies

Sunflower Galaxy (M63)

© NASA/ESA

Medusa Nebula (Abell 21)

Source: Wikipedia commons © Jschulman5555

Orion constellation

© Getty

ASTROSHOTS OF THE MONTH

Get featured in **All About Space** by sending your astrophotography images to **space@spaceanswers.com**

Shaun Reynolds

Location: Norfolk, UK

Telescope: Williams Optics FLT 98 APO

"I became interested in astronomy about five years ago. A friend got a scope and mount as he wanted to get into astroimaging, and he asked me if I was interested as I like photography. My initial response towards astrophotography was a mild interest until we put my Canon 1000D DSLR on his scope. Within a couple of 60-second images, I was totally hooked!"

"WITHIN A COUPLE OF 60-SECOND IMAGES, I WAS TOTALLY HOOKED"

Above: The Heart Nebula (IC 1805) in HST palette using H-alpha, OIII and S2 narrowband filters

Left: The Pleiades (Messier 45). LRGB filters show the dust reflected by this hot, young star cluster

Steve Bassett

Location: West Sussex, UK

Telescope: Sky-Watcher 150P

"I first had a mild interest in astronomy when I was a child and got my first scope aged ten. I remember getting my first view of Saturn through it, which was an incredible thing to see, and I can remember the sense of achievement at finding it using a very basic telescope as well as an alt-azimuth tripod. My interest dwindled as I reached my teens, and it wasn't until I was 30 that a colleague at work reignited it in a big way. In the four years I have been back in the hobby I have developed a keen interest in astrophotography. A lot of my imaging so far has been from my back garden, which is far from being a dark-sky site but has yielded some reasonable results."

Right: The Triangulum Galaxy (Messier 33)

Ollie Taylor

Location: Isle of Portland, UK

"I have been photographing landscapes with the emphasis on the night sky since late winter 2011 after shooting aurorae in Iceland – something I had longed to do for years. Upon returning to the UK, I decided to pursue my interest further after learning how to expose in order to capture the spiral arm of the Milky Way. I slowly developed my photographic style around the skies of the southwest coast. In the right places, the southwest coast opens up to dark skies that appear to stretch out to eternity – just perfect for stargazing."

Above: Faint aurorae captured in Iceland in 2011

Left: Very high-colour processing of the night sky with the foreground of Durdle Door lit up

REVIEW

CELESTRON SKYMASTER PRO 15x70

This binocular offers an amazing stargazing experience, with a good combination of magnification, aperture and portability

Reviewed by Robin Scagell

BINOCULAR ADVICE

Cost: £189 (approx. $253.50)
From: Celestron
Type: Mirrorless
Optical design: Porro prism
Objective diameter: 70mm
Magnification: 15x
Exit pupil: 4.6mm
Eye relief: 17mm
Weight: 1,575 grams
Actual field of view: 4.4 degrees
Apparent field of view: 66 degrees
Close focus: 15 metres
Construction: Centre focus, nitrogen-filled
Coatings: Fully multi-coated

BEST FOR...

- MEDIUM BUDGETS
- PLANETS
- DEEP SKY
- LUNAR
- STARS
- STAR CLUSTERS

Almost every amateur astronomer has some binoculars – even if they have an impressive array of telescopes as well. Binoculars have qualities that telescopes don't: they're instantly available, easy to use, can be pointed at any object in the sky quickly without the need for motors and give a wide field of view. They allow you to use both eyes for observing, which is far more comfortable than using just one eye. They are also comparatively low cost.

Standard everyday binoculars are versatile instruments. The workhorse specification of 10x50 – a magnification of ten and objective lenses of 50mm aperture – is an excellent compromise of usefulness for daytime viewing and night use. At night, stars that are too faint to be seen with the naked eye spring into visibility, while the larger nebulae, galaxies and star clusters become recognisable glows. Just scanning along the Milky Way on a clear night is something that even experienced observers never tire of.

But they do have their limitations. A magnification of ten is just a bit too low to reveal many of the fainter deep-sky objects, and inevitably you'll want to see more. This is where 15x70s come in. The increased power is enough to show you many more objects, while the binocular is still comparatively portable.

You may think that you can use binoculars instantly, but you do need to set them up for your eyesight. This takes just a few seconds, but is essential because there is a wide variation in the separation and strengths of eyes. First you need to adjust the separation between the two halves of the binocular, what's known as the interpupillary distance, until you can see both circles of light merging into one without any shadowing. With the Celestron there is a scale of separation running from 58 to 72mm, so make a note of this so that you can adjust them instantly whenever you use them. Next you need to adjust the focus. Start by focusing on an object with your left eye, using the centre focusing wheel, then shift your attention to your right eye. The right eyepiece can be twisted to adjust the focus. Focus it until the same object is sharp, and again note the setting. In this case the scale of dioptres isn't marked, so it's a matter of guessing which indentation on the black casing is right for you. We would have expected a binocular in this price range to have the plus or minus dioptre markings picked out in white for easy and fuss-free use.

Once you have them adjusted, the view through the binocular is in a league of its own compared with standard 10x50 models. Point them at a bit of sky and the stars will leap out at you. You'll

Left: The binocular features a tripod bush so accessories can be attached

"THE INCREASED POWER IS ENOUGH TO SHOW YOU MANY MORE OBJECTS, WHILE THE BINOCULAR IS STILL COMPARATIVELY PORTABLE"

Left: The sturdy and sleek design complements the stunning views available

be asking yourself where all those bright stars came from. It can be hard to know which bit of sky you are viewing, with so many points of light in view, and on a good night the results can be breathtaking. This is real stargazing. The colours of stars are also much more obvious. We chose to look at a notably red star: fourth-magnitude Mu Cephei. This looks like any other star with the naked eye, but through the 15x70s it burns like a glowing coal. You can see why William Herschel referred to it as the Garnet Star.

The Andromeda Galaxy is a lovely object through the Celestron AstroMaster Pro, and the increased power makes its two companion galaxies, Messier 32 and Messier 110, easy to spot. The famous galaxy pair of Messier 81 and Messier 82 in Ursa Major were also easily visible, the contrast in their shapes obvious. We were also able to see the larger and brighter galaxies in the Virgo Cluster, such as Messier 87. The darker your skies, the more you'll see.

What about planets? A power of 15 is too low to yield any details, but Jupiter has an obvious disc, surrounded by its Galilean satellites. Saturn, while not resolved into a planet and rings, is very clearly elongated. Then the International Space Station came over, and again we were able to see a physical size as it dashed through the field of view. It seemed to be a box shape, but had we caught it in a lighter sky rather than as a brilliant glare in a dark sky, we believe the H-shape of the solar panel array would've been visible. While there were no bright comets around during the test period, the optics would be excellent for viewing a naked-eye comet with their wide field of view and substantial magnification.

Images of stars were excellent at the centre of the field of view, but distortion was evident towards the edges, with the stars appearing as streaks. This is not that disturbing, as a person's vision is only sharp at the centre anyway, but it means that you would have to move the binocular to explore a large star field – to get edge-to-edge sharpness in a binocular of this size you'll have to pay a great deal more.

The sight of the full Moon through the optical system is a showstopper. Using both eyes rather than just one, as with a telescope, gives a dramatic

feeling of depth, even though there is no actual stereo effect for any object more distant than a few hundred metres. Viewing a bright Moon provided us with a good opportunity to look for chromatic aberration introduced by the optics. A trace of false colour is inevitable in any instrument that uses conventional achromatic lenses rather than the much more expensive apochromatic lenses. In this case, with both eyes viewing centrally in the eyepieces, false colour was minimal, displaying the 'apple green and plum' colours which often indicate good correction. Moving the full Moon out of the field of view and looking for unwanted glare showed that baffling of the optics, while not perfect, was good.

As well as the Pro model, Celestron also sells a budget version of this binocular with almost the same specification at nearly half the price. So why spend more? With the Pro version you get a more rugged internal construction, so the binocular is less likely to go out of alignment and give double vision if subjected to knocks, plus they have fully multi-coated optics. This means that all glass surfaces are coated for better light transmission, rather than just some of them. There are various levels of coating, all of which brighten the image, but fully multi-coated optics will give the brightest images for a given aperture. The Pro model is also waterproof and nitrogen-filled to avoid the risk of internal misting. You might think that as you never observe in the rain you don't need waterproofing – as with binoculars designed for bird-watching or yachting, for example – but bear in mind that the clearest nights are often dew-laden.

Observers who wear glasses for long or short sight will probably find that the range of adjustment provided means that they don't need to wear their glasses for observing. But if you have astigmatism or require an extreme dioptre correction, you will need to fold back the rubber eyecups on the eyepieces so that you can press your glasses against them. The binocular is provided with two types of rubber eyecups – standard low-profile and winged, for excluding extraneous light. But we had trouble with both styles; we found them both difficult to fit in place, and once they were fitted they easily came loose and fell off.

The binocular has a generous eye relief of 17mm, meaning you don't need to get your eyes very close to the eyepieces in order to see the full field of view. One major drawback with any binoculars larger than the standard sizes is the difficulty of holding them steady. Hand-holding is possible, but many people will find that the weight of them becomes wearisome after a while, though they are considerably lighter than the much more expensive 16x70 Fujinon binocular that we took the time to compare them with.

> "THE SIGHT OF THE FULL MOON THROUGH THE OPTICAL SYSTEM IS A SHOWSTOPPER"

FOR

- ⊕ Excellent for viewing larger deep-sky objects
- ⊕ Lighter than some other similar-sized instruments
- ⊕ Nitrogen-filled to avoid internal misting
- ⊕ Reasonable price for a quality instrument
- ⊕ Robust construction
- ⊕ Waterproof

AGAINST

- ⊖ Difficult to hold steady for any length of time because of their weight and magnification
- ⊖ Tripod adaptor difficult to use
- ⊖ Rubber eyecaps came loose

Trying to rest them against a wall helps when the objects you are viewing are low down, but when objects are high in the sky this can be difficult. The binocular sports a tripod bush on the central pivot, as do many binoculars, and are provided with a sturdy metal bracket accessory to allow you to fit them to a tripod, or indeed a monopod, which may be more convenient. This bracket also has a shoe for fitting a standard red-dot finder to help you find your chosen targets.

However, when tightening the bracket to the binocular, we found that when it was as tight as needed to prevent wobbling, it was very difficult to undo the bracket from the binocular afterwards. There is a rubber sleeve on the knob intended to give you a better grip, but this just turns uselessly on the inner metal knob. The problem is that the bracket uses a smooth metal washer against the smooth metal surface of the binocular – no chance of a grip. In two minutes we had made a cardboard washer to replace the metal one, giving sufficient grip on the binocular without over-tightening and subsequent removal problems.

The binocular offers a superb stargazing experience at a reasonable price. There are some views that just can't be achieved with a telescope, and while they won't give you close ups of planets or reveal the most distant galaxies, they make up for it by providing dramatic wide-field views under a dark sky.

Below: The binocular is still portable and come with a protective case for storage and transport

FREE FOR EVERY READER!

HOW IT WORKS MAGAZINE
ASTRONOMY FOR BEGINNERS
& 2022 NIGHT SKY GUIDES

HOW IT WORKS ISSUE 155

Ever wondered what would happen if you fell into a black hole or how to build a supercar? **How It Works** is the action-packed magazine that's bursting with the answers to your curious questions - every issue is full of the most exciting advances in science and technology and features everything you need to know about how the world around you - and the universe - works. Get inside the latest iPhone, use science to learn tricks on a hoverboard, discover how robots could soon be administering your medicine, find out how your brain really works, take part in saving our world's oceans and much more. In this issue, discover the story of our home planet, a guide on how to survive nearly anywhere, what happens to nuclear waste, intrepid deep-space probes and much more.

ASTRONOMY FOR BEGINNERS (8TH EDITION)

Astronomy for Beginners tells you everything you need to know to view the wonders of the night sky. From the basics - such as setting up a telescope, reading star charts and using binoculars - through to keeping logbooks and joining a club, this new edition will help you learn all the essential techniques and practices. Whether you want to identify constellations or photograph craters on the Moon, these guides are the place to start. **Astronomy for Beginners** also helps you choose the right equipment and set up your telescope, provides practical advice to help astronomy novices get going with astronomy, explains how to use sky charts and learn what incredible sights you can view all year round as well as an introduction to astrophotography.

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IN THE SHOPS

The latest books, apps, software, tech and accessories for space and astronomy fans alike

2

1

3

FOR HOT DRINKS

WHSMITH CELESTE TRAVEL MUG

Cost: £12.99 (approx. $17.20)
From: WHSmith

1 This celestial-inspired travel mug from WHSmith is perfect for keeping your drinks warm during the colder winter months – and will look great in your kitchen or office too. Embellished with a golden stellar scene, the travel mug is the ideal accessory for the space lover in your life. If you like this design, then you'll be pleased to know there are other products available in the Celeste range at WHSmith, including notebooks, pens and water bottles.

FOR FUN

TERRAFORMING MARS BOARD GAME

Cost: £47.99 / $69.95
From: Amazon

2 One to five players can compete to gain the most points towards raising the habitability of the Red Planet for future human visitors. Players gain points by raising Mars' temperature, the planet's oxygen level and by creating and expanding oceans. The game features several card categories that allow the players some control over the level of difficulty. Project cards stimulate the imagination by tasking players to do things like introduce plant life and build cities, and there are more than 200 different projects to complete.

FOR YOUR HOME

ASTRONOMY PHOTOGRAPHER OF THE YEAR CALENDAR 2022

Cost: £9.99 (approx. $13.20)
From: calendarclub.co.uk

3 Start 2022 organised and full of awe with this stunning calendar packed with astronomical images. Produced in partnership with the Royal Observatory Greenwich's Astronomy Photographer of the Year competition, this calendar features all 12 stunning images spanning the different competition categories, including People and Space, Our Sun, Stars and Nebulae and Skyscapes. It's a 12-month, date-grid calendar with a punched-hole hanger. Moon phases and international holidays are included on the calendar.

5

4

"THE FLEECE LINING AND STURDY OUTER LAYER WILL HELP PROTECT YOU FROM THE ELEMENTS"

© ESO

6

FOR WINTER OBSERVERS

CELESTRON FIRECEL PLUS

Cost: £29.99 (approx. $39.70)
From: Celestron

4 Stargazing can be a chilly affair in winter. The FireCel Plus wards off the cold by serving as a rechargeable heater with dual-side heating or single-side heating for when it's in a pocket. The hand warmer is equipped with four LED lights that can serve as a regular white-light flashlight when you're hunting for a good observing spot as well as a red-light flashlight to protect your night vision. Both light colours have five different blinking modes, including SOS patterns to help signal others in an emergency.

FOR FUN

SCIENCE MUSEUM IMPOSSIBLE JIGSAW PUZZLE

Cost: £15 (approx. $19.85)
From: shop.sciencemuseum.org.uk

5 Fancy a challenge of cosmic proportions for the New Year? How about this formidable jigsaw puzzle from the British Science Museum? Composed of 1,000 pieces, this product is sure to challenge even the most experienced puzzler. Is it worth it? Absolutely! Once assembled, you're rewarded with a stellar work of art. The Science Museum recommends this product for puzzle fanatics ages 14 and over. It's not suitable for young children under three years as it contains small parts.

FOR WRAPPING UP WARM

EUROPEAN SOUTHERN OBSERVATORY WINDBREAKER

Cost: €45 (approx. £38.50 / $50.95)
From: eso.org

6 Keep yourself warm and comfortable when stargazing with this robust European Southern Observatory windbreaker jacket. The jacket is adorned with an embroidered ESO logo and the ESO website is featured on the left sleeve. The cosy fleece lining and sturdy outer layer will help protect you from the elements, and the inner and outer pockets will help keep your belongings safe. Both stylish and practical and available in sizes S, M, L, XL and XXL, this ESO windbreaker is the perfect winter accessory for those crisp winter nights.

HEROES OF SPACE

CHRISTINA KOCH

A record-breaking astronaut who could be one of the first women to step foot on the Moon

Koch is a class of 2013 NASA astronaut

© NASA

Koch is an inspirational, record-breaking NASA astronaut who might one day make it to the Moon. On 9 January 2020, Koch celebrated her 300th day in space aboard the International Space Station (ISS). By the time she landed back on Earth on 6 February, she had broken the record for the longest time spent in space by a woman. But that's not her only historic achievement. Just a few months prior, Koch and another female astronaut, Jessica Meir, completed the first all-woman spacewalk.

Koch was born in Grand Rapids, Michigan, and grew up in Jacksonville, North Carolina. From a young age she wanted to be an astronaut, joining her middle school's 'Rocket Club'. Trips to the Kennedy Space Center in Florida only solidified that dream. Koch attended North Carolina State University in Raleigh and completed a bachelor's degree in electrical engineering as well as a bachelor's in physics. She then completed her master's in electrical engineering.

After completing her studies, Koch joined NASA as an electrical engineer at the Goddard Space Flight Center in Greenbelt, Maryland. While at Goddard, Koch worked in the Laboratory for High Energy Astrophysics on instruments for several space science missions. After her time at Goddard, Koch worked in Antarctica at the Amundsen-Scott South Pole Station and Palmer Station. From there she returned to her electrical engineering roots and worked at the Johns Hopkins University Applied Physics Laboratory, contributing to instruments on the Juno spacecraft and Van Allen probes.

In 2013 Koch was selected as a member of NASA's 21st astronaut group. After six years of intense training, she launched on her first space mission to the ISS on 14 March 2019 from Baikonur Cosmodrome on a Soyuz spacecraft. She was joined by astronaut Nick Hague and Russian cosmonaut Aleksey Ovchinin. In her tenure on the ISS, Koch served as a flight engineer on expeditions 59, 60 and 61. While aboard the ISS, Koch worked on several scientific studies that covered human biology, Earth science, technology development and more. She also completed three all-woman spacewalks out of her six total spacewalks, spending a total of 42 hours and 15 minutes in the vacuum of space.

18 October 2019 wasn't originally supposed to be a historic day. The first all-woman spacewalk was meant to occur on 29 March, but an issue with spacesuit sizes delayed that plan. The most important part of the spacesuit is a hard plastic torso piece that holds the electronics that control all the suit's systems. An ill-fitted spacesuit can lead to serious safety issues, and reconfiguring the suit can take up to 12 hours. Koch and her colleague Anne McClain were scheduled to participate in a spacewalk together, but there was only one spacesuit made to fit McClain or Koch, so McClain swapped places with Nick Hauge so that Koch could wear the one spacesuit that fit. By October, the crew had reconfigured another suit to fit Jessica Meir, who joined Koch on the first all-woman spacewalk. For more than seven hours, the pair worked on replacing a battery unit that failed to activate after new lithium-ion batteries were installed. Koch returned to Earth on 6 February 2020 after spending 328 days in space, setting the record for the longest space mission by a woman.

Space travel has traditionally been designed for men. The physical embodiment of that fact is NASA's spacesuits, which had been designed with a man's physique in mind. Koch's participation in the first all-woman spacewalk was a groundbreaking accomplishment for female astronauts and all non-male people around the world. In December 2020, Koch was selected as one of the astronauts who will journey to the Moon as part of NASA's Artemis lunar exploration program. This means she could be one of the first – if not the first – woman to step foot on the Moon.

All About Space

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Cover images
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Photography
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Printed by William Gibbons & Sons Limited, 26 Planetary Road, Willenhall, Wolverhampton, West Midlands, WV13 3XB

Distributed by Marketforce, 5 Churchill Place, Canary Wharf, London, E14 5HU www.marketforce.co.uk Tel: 0203 787 9060

ISSN 2050-0548

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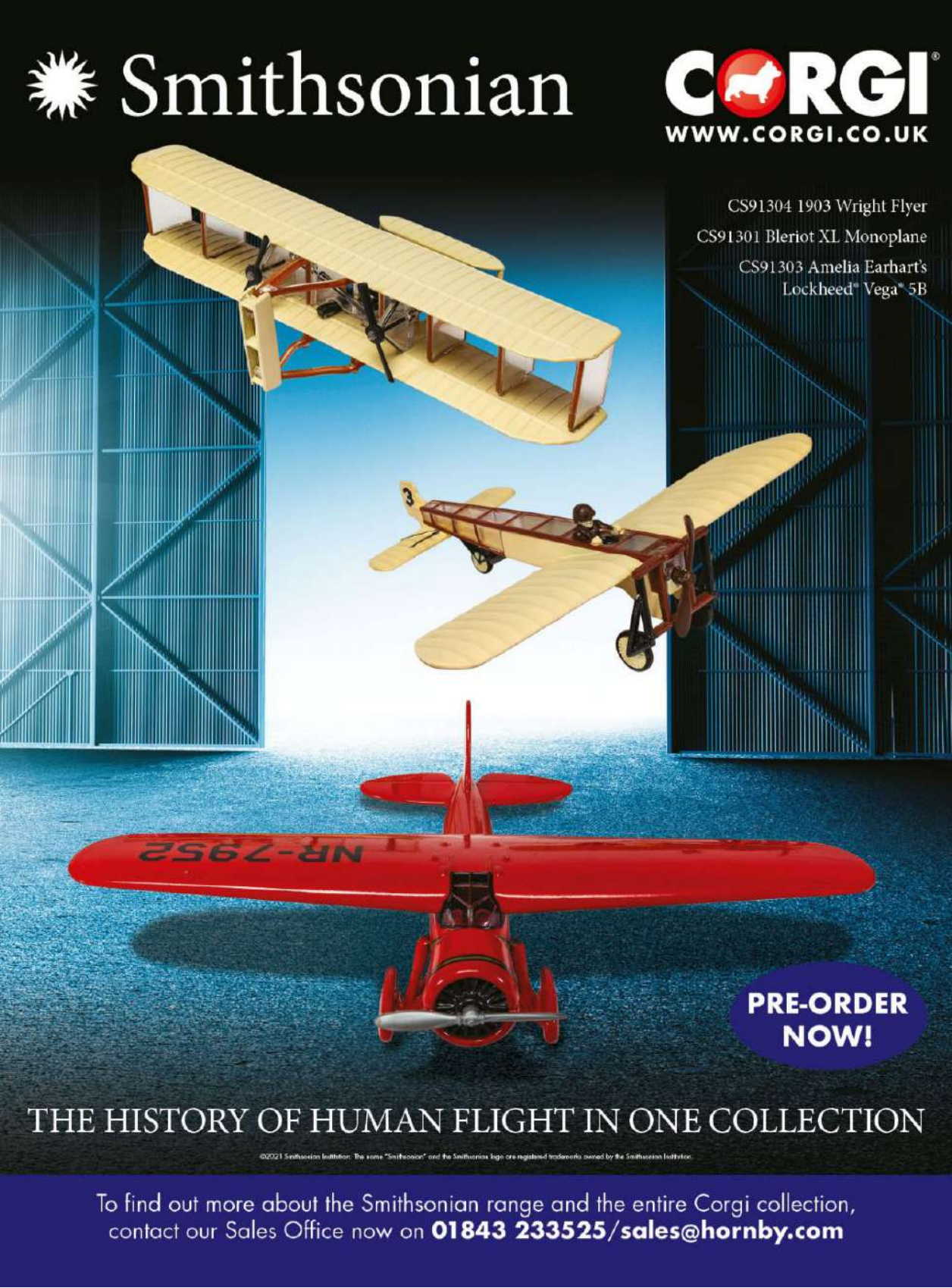
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